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Institute and Related Activities

220-Kv. Transmission

Southern California Edison Company System, and Some 220-Kv. Researches

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Review of the Subject:—*The rapid growth in the demand for electric power and the increasing distances to which transmission is desirable, have constantly forced the use of higher transmission voltages.*

The Southern California Edison Company, having two single-circuit tower lines 241 miles long from its Big Creek hydroelectric plants to near Los Angeles, had the alternative of either duplicating these lines or of raising the voltage upon them. The latter procedure was found to be vastly the more economical. Other things being equal, the amount of power that can be transmitted varying with the square of the voltage, and the existing voltage being 150 kv., a doubling of capacity will result by raising the voltage to 220 kv.

To avoid the difficulties inherent in changing over generating and substations built for the lower voltage, and in which adequate clearances would be very difficult to obtain, it was decided to use auto-transformers at each such station, transforming between 150 and 220 kv. Additional sectionalizing switching stations will be built in the line, making six in all, so that the rebuilding of the line may be done without crippling service, and insulator testing can be done at any convenient time. An extension of the line 30 miles in length will be built so that the completed 220-kv. system will be 270 miles long.

Preparatory to the final design, a considerable amount of investigation and research was carried on. The best form of insulation that would fit existing towers had to be determined, standard suspension insulators being preferred over new untried designs. Laboratory high-voltage tests of insulation at oscillator frequencies of 30,000 and 50,000 cycles and at continuous 60 cycles were undertaken in order to get as much information as possible, all such tests being made in dummy towers so as to duplicate actual conditions as nearly as possible.

The next step was to equip 27 miles of one Big Creek line with additional insulators and shield rings and carry out field tests. This section of line was energized to 280 kv. for one month, and to 241 kv. for about five months, extending through the greater part of the rainy season. Considerable care was taken to obtain reliable measurements of voltage, current and corona losses.

The results of the laboratory and field tests lead to the firm belief that nothing extraordinary will happen with 220-kv. transmission. The difference between operation at this voltage and existing voltages will be only of degree. There seems to be no pressing need of new designs of insulator so that as new designs are developed they may be given the acid test of time on unimportant lines where their failure will be of small moment.

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The imminent increase of transmission voltage from the existing maximum of 165 kv. to 220 kv. has been forced by the extremely rapid increase in the demand for electric power, which on the one hand in certain cases, rendered the acquisition of rights of way and building of new lines difficult to effect within the allowable time and upon the other, has led to the transmission of such large quantities of power over long distances, that the higher voltage was required to realize the lowest total cost per kilowatt-hour delivered.

The Southern California Edison Company was confronted with the problem of doubling the transmission capacity from the Big Creek hydroelectric plants to the territory surrounding Los Angeles. The solution depended upon the conversion of the two existing 150-kv. tower lines to permit of operation at 220 kv., together with such terminal changes as would allow existing plants to feed into the lines, substations to take power from them, and future extensions to be made.

The general plan decided upon was as follows:

Big Creek No. 1 and No. 2 plants of 32,000 (48,000 ultimate) and 48,000-kw. capacity respectively will remain unaltered, delivering power at 150 kv. to two 52,500-kv-a. auto-transformer banks installed close to each plant. Each auto-transformer bank will have sufficient capacity to convert the whole output of its respective plant to 220 kv., so that there will be full capacity in reserve units.

Big Creek plant No. 8, of 22,500-kw. capacity, was designed and built for 220-kv. operation, but is now operating upon 160-kv. taps of 220-kv. transformers. Upon completion of the 220-kv. system the transformers will be connected for the higher voltages and the plant will feed directly into the 220-kv. lines.

Big Creek No. 3, now under construction, is designed for 220-kv. operation.

The Vestal substation, the first tap off the lines—109 miles from Big Creek No. 1—will be fed through two 52,500-kv-a. auto-transformer banks. The present terminal substation at Eagle Rock, 241 miles from Big Creek No. 1, will have two 110,100-kv-a. auto-transformer banks just outside the station. These substations will continue to operate as before, being fed at 150 kv. from the auto-transformers.

To be presented at the Pacific Coast Convention of the A. I. E. E., Vancouver, B. C., August 8-11, 1922.

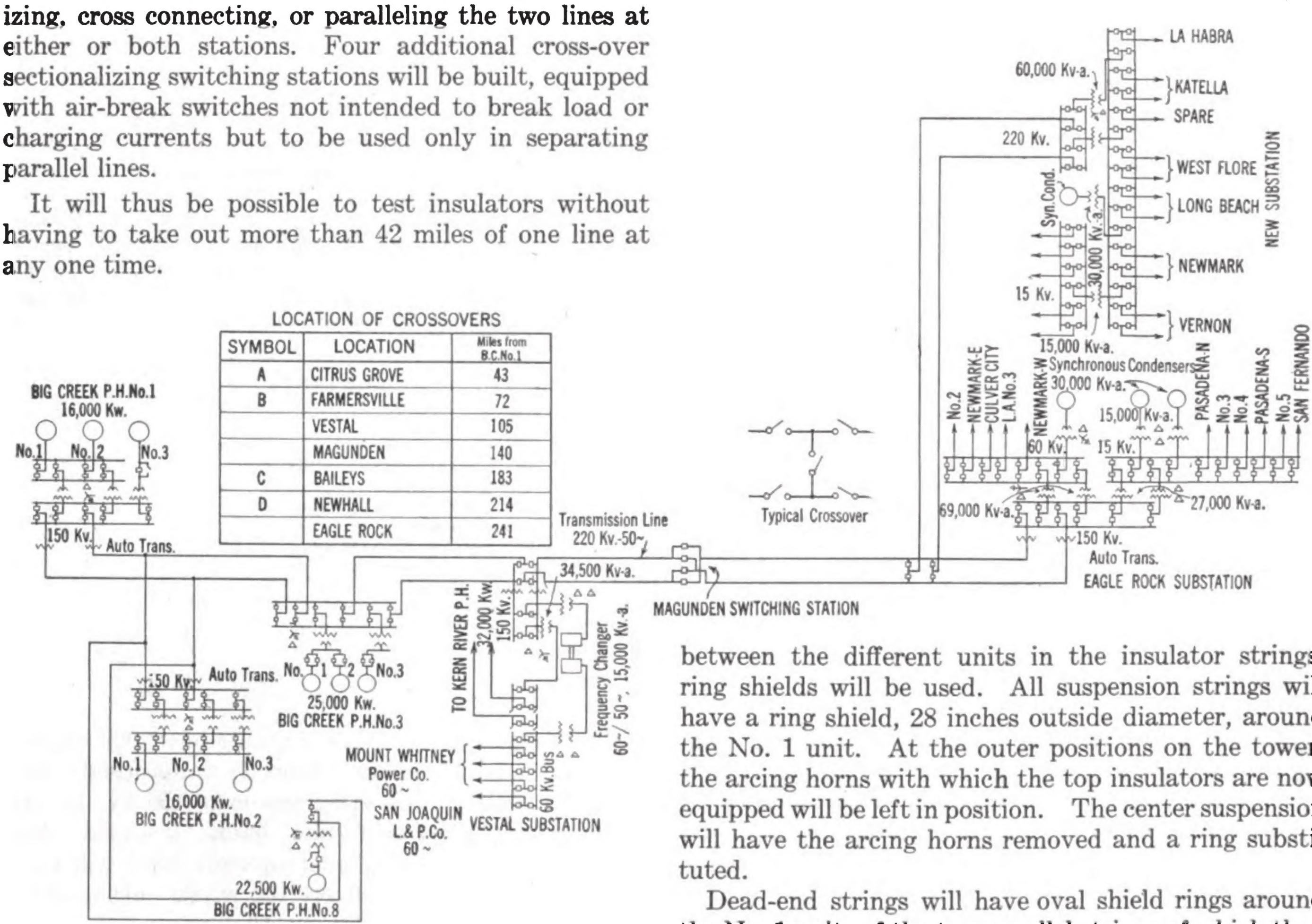
All auto-transformers will be star-connected, solidly grounded, with tertiary windings of kilovolt-ampere capacity equal to the transformer rating of the auto-transformer itself, and with a tertiary reactance of from 10 to 13 per cent.

At present the only switching station in the lines is at Magunden, 140 miles from Big Creek No. 1 and 101 miles from Eagle Rock. Oil switches of 220 kv. will be installed here, also at Vestal, permitting sectionalizing, cross connecting, or paralleling the two lines at either or both stations. Four additional cross-over sectionalizing switching stations will be built, equipped with air-break switches not intended to break load or charging currents but to be used only in separating parallel lines.

It will thus be possible to test insulators without having to take out more than 42 miles of one line at any one time.

A 30-mile extension of the Big Creek lines will be built from Eagle Rock substation, or nearby, to a new substation which will lie east of Los Angeles and will deliver power to a rapidly developing industrial section of the city. Upon this line where no limitations of old construction exist, thirteen suspension units will be used.

In order to obtain better voltage distribution as



LOCATION OF CROSSOVERS

SYMBOL	LOCATION	Miles from B.C.No.1
A	CITRUS GROVE	43
B	FARMERSVILLE	72
	VESTAL	105
	MAGUNDEN	140
C	BAILEYS	183
D	NEWHALL	214
	EAGLE ROCK	241

FIG. 1—SINGLE LINE DIAGRAM—FIRST UNIT OF 220-KV. TRANSMISSION OF SOUTHERN CALIFORNIA EDISON COMPANY

This rather extreme amount of sectionalizing was considered advisable, as the number of insulators decided upon, viz. eleven to a suspension string, is about the minimum number that will afford satisfactory operation, and all the insulators on the lines will be meggered at least once a year and any accumulation of bad units forestalled.

Even had these considerations not prevailed, the sectionalizing was necessary for the reconstruction of the lines for 220 kv., as longer sections could not be taken out of service under the existing load conditions without undue drop in voltage.

It is planned to replace some of these air-break cross-over switches with oil switches in the future, with a view to automatic sectionalizing in cases of line trouble.

between the different units in the insulator strings, ring shields will be used. All suspension strings will have a ring shield, 28 inches outside diameter, around the No. 1 unit. At the outer positions on the tower, the arcing horns with which the top insulators are now equipped will be left in position. The center suspension will have the arcing horns removed and a ring substituted.

Dead-end strings will have oval shield rings around the No. 1 units of the two parallel strings of which they are composed. At the tower end the existing arcing horn will remain.

Tie-down strings will have a shield ring around the top No. 1 unit, the numbering convention being to count always from the conductor towards the grounded end. The shields used at the bottom of suspension top of tie-down and line end of dead-end strings will be made of cast aluminum alloy. The rings for the top of center suspension strings will be of galvanized tire iron. All rings are so supported that they will retain their normal position relative to the axis of the insulator string whatever the inclination to the vertical of the latter may be. This material will all be manufactured locally.

For the purposes of voltage regulation all generating plants are equipped with Tirrell regulators, maintaining constant voltage at the generator.

At Eagle Rock substation will be one 30,000-kv-a.

and two 15,000-kv-a. synchronous condensers which are now in operation. The new 220-kv. substation east of Los Angeles will initially have one 30,000-kv-a. condenser and will be so designed that in the future, extensions can be made to accommodate three or more additional condensers, all condensers regulating for constant voltage by Tirrell regulators.

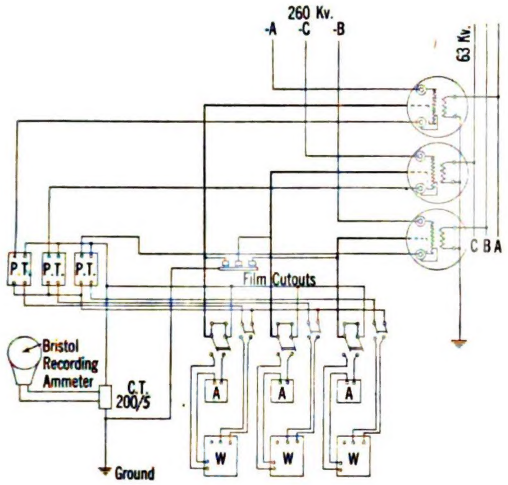


FIG. 2—CONNECTIONS OF ENERGIZING TRANSFORMERS AND METERS USED ON FIELD TESTS

It is calculated that a total condenser capacity of 180,000 kv-a. will regulate for 240,000 kw. transmitted over two lines with zero regulation from generator to substation, the power factor of the load being taken at 0.85 lagging. While there are some theoretical considerations which render zero voltage regulation very attractive, it costs money, and there will be many cases where the marked increase in carrying capacity of the line, due to a slight drop in voltage from generator to substation, will be hard to overlook from an economical standpoint. This is a matter of distinguishing between feeder transmission lines and high-tension bus-bars and no general rules will apply.

Such calculations as have been made do not indicate the advisability of installing condensers at the middle point of the line, entirely satisfactory regulation and economy of transmission being effected by concentrating the condensers at the receiving end. It does not therefore seem necessary in this case to distribute condensers as has been done for several years past upon the Southern California Edison 60-kv. system, where, to describe one instance, in the transmission from Kern River No. 1 hydroelectric plant to Colton substation (a distance of 170 miles) synchronous condensers were installed at 110 and 143 miles from Kern River and at the end of the line, affording proper voltage regulation at intermediate points of the line and reducing line losses.

The 220-kv. oil switches will have a rupturing capacity of not less than 1,200,000 kv-a. Disconnecting switches for station use will be mounted upon separable post-type insulators. At Big Creek No. 8 these took the form of tripod posts, each leg composed of 14 standard 10-inch suspension disks connected by bolted flanges.

The general diagram of connections is shown in Fig. 1. This represents what may be called the first unit of 220-kv. transmission. The diagram for switching stations is given in Fig. 2. These stations are omitted from Fig. 1.

The existing clearance to ground upon the Big Creek lines is 25 ft. The reconstruction for 220-kv. entails the raising of a great percentage of the towers to afford a minimum clearance of 30 ft. to ground in all country susceptible of cultivation. In mountainous and the more inaccessible country, clearances will be established in accordance with rulings of the State Railroad Commission.

The towers will be raised bodily without interference with conductors or ground wire, and a structural steel, vertical sided extension frame bolted between them and their old foundation anchors, which will not be disturbed in any way. Among other advantages, the benefit of having old well settled foundations will be retained.

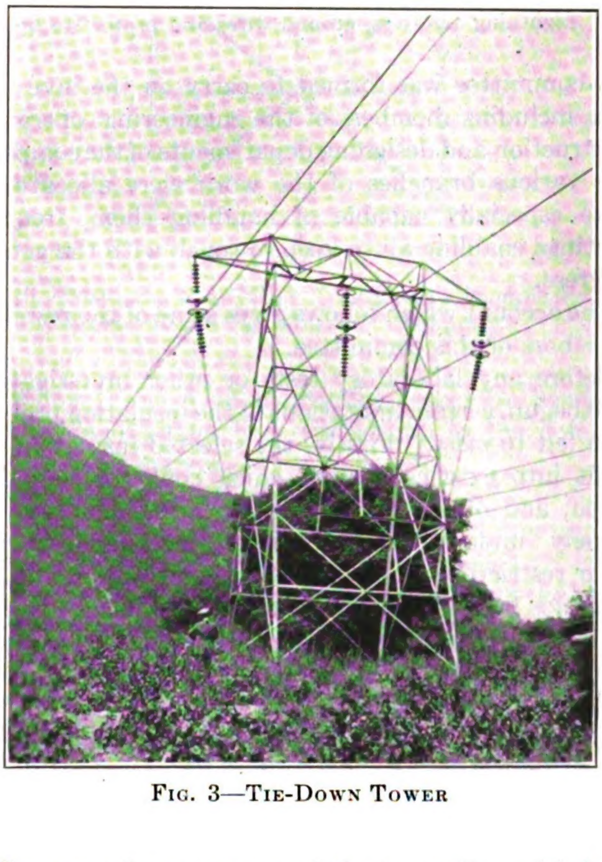


FIG. 3—TIE-DOWN TOWER

The general appearance of the tower line with insulators equipped with shield rings is shown in Fig. 3 which illustrates a tie-down tower. A dead-end insulation is depicted in Fig. 4, both illustrations from the *Electrical World*. The rings that will be installed on the balance of the lines will differ from those illustrated in being only 2½ in. instead of 5 in. deep.

All this work is scheduled to be accomplished this year, so that actual operation at 220 kv. should be started quite early in 1923.

220-Kv. Investigations

When it was decided that investigations should be begun as to the best manner of making the change to 220 kv., a program was laid out which included:

1. The effect of shield rings, enlarged conductors, and other devices and expedients for improving voltage distribution over strings of suspension insulators.
2. The behavior of strings of various numbers of insulators under high-frequency, high-voltage oscillator discharges.
3. A duplication to a certain extent of the experiments made with the oscillator, and such other investigations as were desired, using 60-cycle high voltage.
4. Test under line conditions of the scheme of insulation which would be decided upon as a result of the laboratory experiments.
5. As extensive corona tests as were practicable, to determine definitely the sufficiency of the existing cables on the Big Creek lines.
6. To note such other matters of practical or academic interest as might arise or develop during the tests.
7. A complete study of line regulation, synchronous condenser capacities required, and the most economical size of conductor for new lines.
8. Tower design, single circuit vs. double circuit towers, most economical span, clearance to conductor.
9. Lightning arresters, ground wires and protective apparatus.

A committee was formed to carry on the investigations including members of the engineering, operating, construction and designing departments of the company. The various branches of the work were allocated to those especially capable of handling them, frequent meetings enabling all to keep in touch with the general progress.

The account which follows gives some of the results of the labors of this committee.

Before any laboratory tests or other investigations were begun, certain limitations of the insulation problem were felt to exist. Firstly, the selected insulation had to fit into existing towers which could of course be raised, and otherwise modified, but which it was extremely undesirable to weaken mechanically; this latter restriction practically preventing any increase of clearance between conductor and tower being obtained by modification of the tower structure. Secondly, it was felt that every effort should be made to utilize standard suspension insulators.

The modern 10-inch suspension insulator has reached a high perfection and can be bought of several manufacturers. Several years were required to bring this insulator up to its present excellence and to prove it. The insulator is an innocent looking little thing, but it is doubtful if the manufacturer, and still less the user, can always forsee the troubles that may arise from making even apparently minor changes in its shape. At all events the user cannot be sure that a new type will be satisfactory for his purpose until it has been tried out for several years. It therefore appeared logical and to be better business to use the standard insulator whose behavior and endurance are fairly well-known, predicated always upon satisfactory insulation being obtainable rather than to experiment with something new.

This point of view is not to be taken as indicating that no further advance in the art of insulator design is to be expected, far from it, but it is felt that new types should be tried out upon the less important lines. Deterioration from age can probably be just as well determined upon 60-kv. lines as upon those of 220-kv. It is also felt that the operating companies owe it to the advancement of the art to afford facilities for trying out new designs, but they cannot afford to jeopardize important trunk lines in so doing.

Laboratory Tests upon Insulation

Voltage Distribution. As is well-known, the several units of our unshielded suspension string of similar insulators do not divide the total voltage across the string equally between them. This may lead to a displacement current discharge across a heavily stressed unit if the surface condition of the porcelain is poor from dirt and moisture; such a partial failure of the string may set up oscillations followed by a string flash-over. Whether any such action actually occurs in practise is open to question. Efforts to render the surface of a string of insulators conducting with salt solution have only given negative results in the sense that before a non-unit string, normally used at 87 kv. to ground, could be made to flash over at as low a voltage as double line potential, an amount of conducting material had to be deposited upon its surface that was many times that found upon insulators in ordinary service.

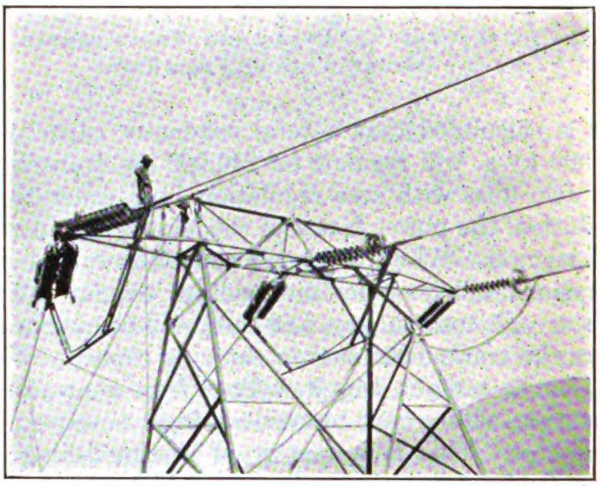


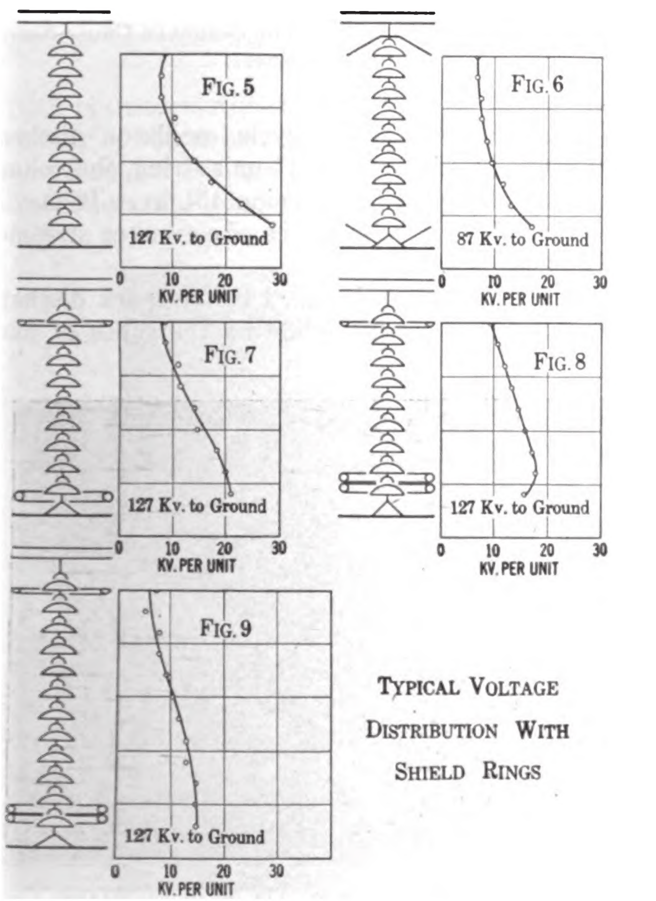
Fig. 4—Erecting Shield Rings on Dead-End Tower

It seems advisable however to equalize this voltage to a certain degree as between units in a string. Through the kindness of Prof. Harris J. Ryan, a series of tests with the high-voltage potentiometer was made at Stanford in 1920 and 1921 to determine the quanti-

tative effect of shields of various proportions. Typical distribution curves are shown in Figs. 5, 6, 7, 8 and 9. Practically any desired distribution can be obtained, even with strings composed of insulators all of the same kind, and further variation and complication is obtainable by mixing units of different internal capacities.

With all similar units in the string it is difficult to obtain a uniform voltage distribution in long strings without using very large and expensive shields, and suffering an excessive reduction in the flash-over voltage of the whole string. Fortunately, as will be further discussed later, it is actually detrimental to have a close approach to uniform distribution and still worse to have an inverted distribution with less voltage across units near to the line than across others.

As a firm basis from which to start it was determined that the maximum voltage across any unit must not exceed that in the existing Big Creek line under normal operation at 150 kv. As shown in Fig. 6 this amounts to 16.8 kv. when all insulators are good and to 21.5 kv. with one bad unit in the string.



FIGS. 5 TO 9—VOLTAGE DISTRIBUTION WITH AND WITHOUT SHIELD RINGS
Tests at Stanford.

The design of ring finally adopted (See Fig. 10) gives a maximum of 17.0 kv. when all insulators are good and 20.8 kv. under the worse condition for one bad unit.

It was found that extension downward of the outer lip of the inverted U-shaped ring, making the ring twice its original depth, had no measurable effect upon the voltage distribution. Similar deepening of the inner lip had, however, a noticeable effect in reducing still further the voltage across the No. 1 unit.

The additional cost of deepening the ring in this way was considerable which the small effect produced did not justify.

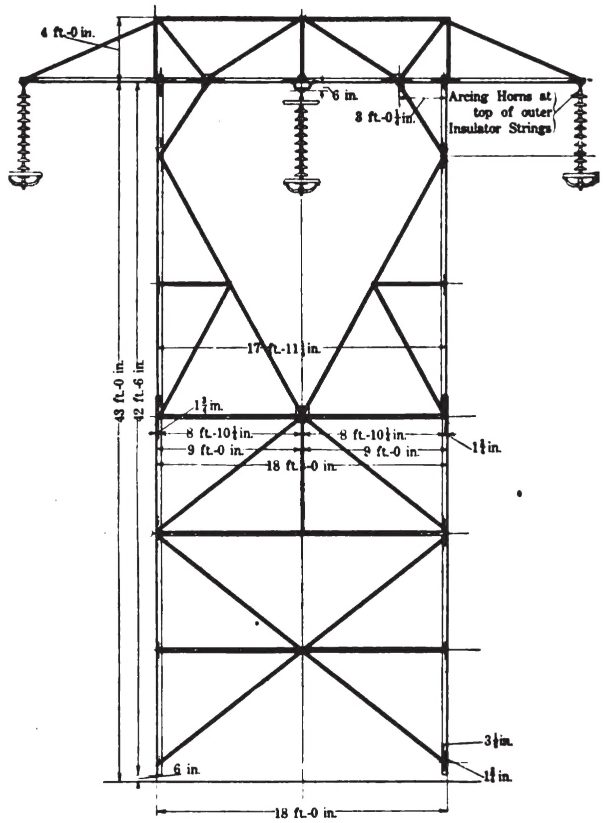


FIG. 10—STANDARD BIG CREEK TOWER WITH INSULATION AND SHIELD RINGS AS FINALLY ADOPTED

Arc-over. The most instructive test of an insulator is its behavior under high voltage up to the point of arc-over or flash-over.

Overstress of particular units and parts of units becomes apparent in the dark by the formation of corona, and the path taken by the discharge when flash-over occurs gives a valuable indication of the likelihood or otherwise of damage being done to porcelain by arc-overs on the line.

A great number of studies was made with Prof. Ryan with oscillator discharges at about 50,000 cycles, with Mr. A. O. Austin at 30,000 cycles, and with Mr. F. W. Peek, Jr. at 60 cycles. It was thus hoped to obtain information upon the behavior of high-frequency effects, which may or may not actually occur in the line, and also to determine the factor of safety to normal-frequency voltages.

These tests were all made with insulators suspended in dummy towers so that the flux distribution might be approximately the same as it would be on the line.

This precaution is necessary, and it may here be

emphasized that flash-over tests made under different conditions as to grounded insulator supports and energized conductors are not comparable for the same insulator arrangements.

The path of the discharge with oscillator frequencies and blue snappy flash discharges follows quite approximately the lines of flux distribution existing just before

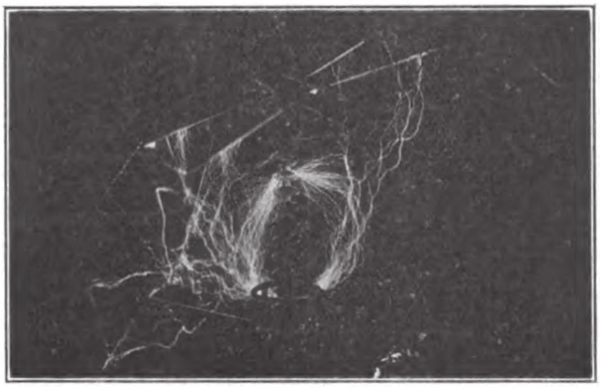


FIG. 11—FLASH-OVER AT 50,000 CYCLES
Test at Stanford.

discharge occurs. With 60-cycle arc-overs this same general direction of the initial discharge is followed, the power arc which immediately follows is mobile, and flashes around with air currents and the reaction due to its own field.

Fig. 11 shows oscillator discharges at 50,000 cycles, the top three units of a 12-unit string being short-circuited with fine wire. The discharges are seen to follow the lines of force in a general way.

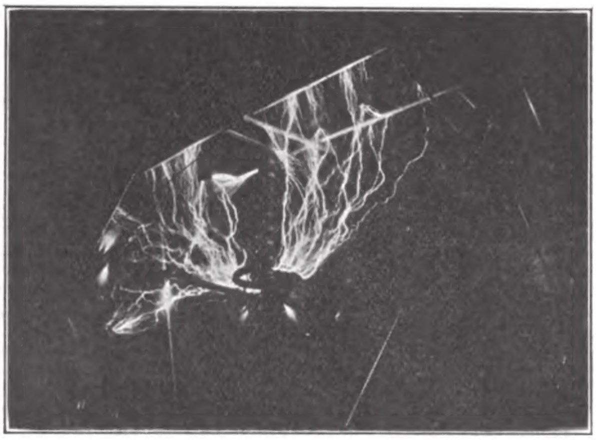


FIG 12—FLASH-OVER WITH INVERTED U-SHAPED RING
Test at Stanford.

Figs. 12 and 13 show arrangements identical except as to the cross-sectional shape of the shield ring. In Fig. 12 the ring has a Ω section, and in Fig. 13 the ring is made of round pipe. It will be noticed that the discharges start from the outer lower edge of the ring in Fig. 12 and are directed further outward from the insulator string than in Fig. 13, where one discharge cascaded the top three units. These illustrations represent 30 closings of the switch in the oscillator circuit. At each closing, lasting perhaps one second, the discharge would usully take place along only one of the flashes shown, although occasionally a flash-over would split between two or three directions.

FIG. 13—FLASH-OVER WITH RING OF CIRCULAR CROSS-SECTION
Test at Stanford.

Fig. 14 shows a 30,000-cycle oscillator discharge under artificial rain upon an 11-unit string, the voltage, as measured by sphere gap, being 451 kv. It may be noted that there is no evidence of corona or streamers on the insulators.

In Fig. 15 attention is called to the spark discharge to the top of the string following the tubes of force.

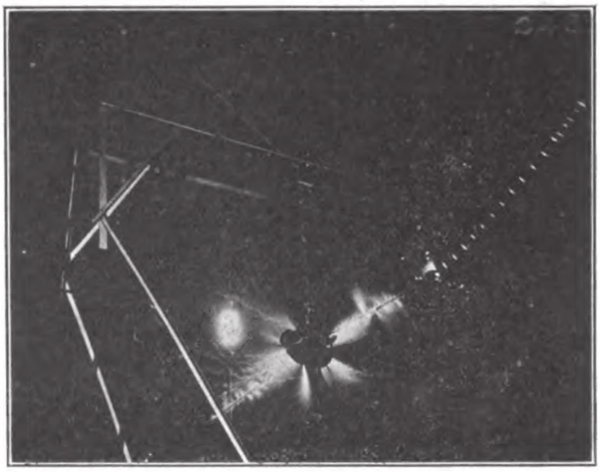


FIG. 14—FLASH-OVER IN ARTIFICIAL RAIN AT 30,000 CYCLES
Test at Barberton.

The insulator string is so long, 13 units, that the majority of the discharges goes to the tower braces. The absence of corona on the insulators may again be noted.

Figs. 16 and 17 illustrate the effect of the shield ring in directing the arc outward from the insulators in the case of flash-overs under rain. There is not any

lowering of the flash-over value although the arcing distance is reduced four inches by the ring.

Fig. 18 shows a flash over a dead-end string equipped with shield ring and arcing horn such as will be used on the line.

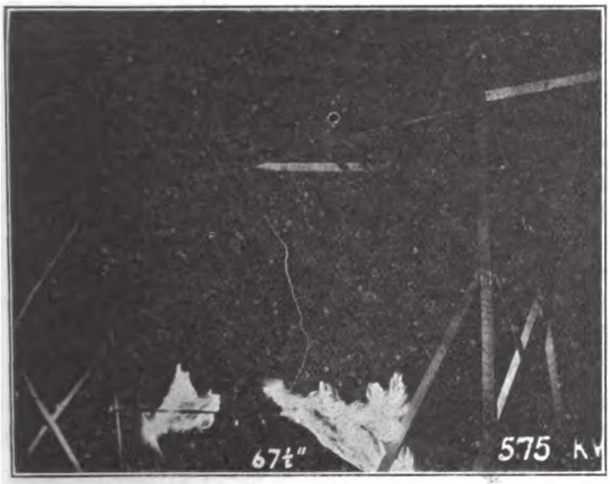


Fig. 15—Arc-Over, 13 Insulators with Deep Shield Ring
Test at Pittsfield.

With both oscillator and 60-cycle discharges there is cascading of the string, or some portion of it, at those parts where flux reenters the string, or expressed differently, where the slope of the voltage distribution

Fig. 16—Arc-Over in Artificial Rain, with Deep Shield Ring
Test at Pittsfield.

curve changes sign as in Fig. 19. The oscillator seems to cause rather more cascading than does 60-cycle voltage.

In Figs. 20 and 21 is summarized a number of arc-over tests at 60 cycles with different numbers of units in the string. These tests were made with different kinds of shield rings placed at various heights above the conductor, thus giving different arc-over values for the same length of string. Points shown as full circles indicate tests where cascading occurred. Clear circles are for tests where the arc-over was clear

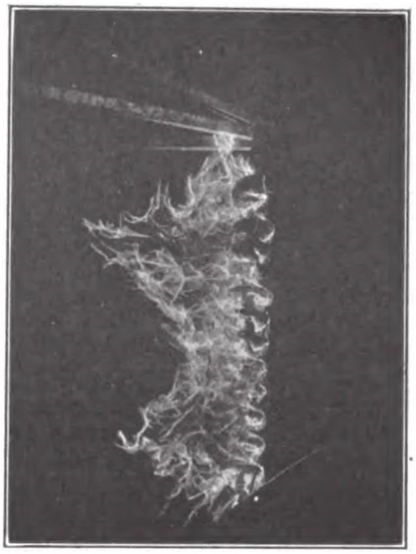


Fig. 17—Arc-Over in Artificial Rain—Lower Arcing Horns Only
Test At Pittsfield.

of the string. Some tests were made with one or more units short-circuited with fine wire to represent bad units; in such cases the test is plotted on the chart for the number of good units. There is a fairly well

Fig. 18—Arc Over Dead-End String
Test at Pittsfield.

defined line of demarkation between the regions of cascading and of clear arc-over, which is interpreted as indicating that, for the particular tower arrangement used, a certain length of string, or number of units, can be forced up to a certain maximum arc-over voltage without cascading, but that if, by lowering the shield

ring for instance, the flash-over voltage is increased, then cascading will occur. The two curves show the extent to which the clear arc-over voltage is affected by the tower structure surrounding the center conductor, as compared with the outer conductor.

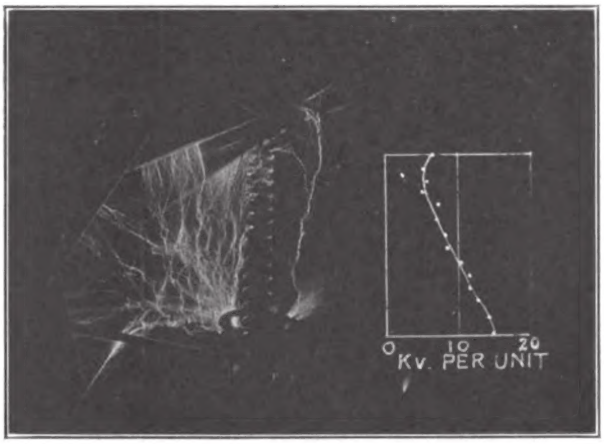


Fig. 19—Flash-Over at 50,000 Cycles Showing Cascading in Relation to Voltage Distribution
Test at Stanford.

The relation between the arcing distance, measured in a straight line and not along the path of the discharge, and voltage is shown in Fig. 22 with, for comparison, the ordinary spark gap curve for points.

Arc-over under rain conditions will start as a cascade string and flare out away from it, at all events in those cases where a gradual diminution in unit voltage duty obtains along the string. No quantitative evidence has been obtained as to how great a part is borne by the outward flux from the string in forcing out the arc from a wet string, but the tendency is in the right direction and should be taken advantage of. Such arcs over wet strings are shown in Figs. 16 and 17; the initial discharge is plainly marked, the whole mass of flame not existing all at one time but being a superimposed record of the wanderings of the arc.

To settle the question as to whether dirt or moderate roughness of the surface of the ring would materially affect the flash-over value the experiment was tried of attaching a pointed piece of wire one-half inch long to the ring, the wire sticking out normal to the ring surface. No difference in flash-over value could be detected whether the point was in position or not. It was concluded that the ordinary roughness of commercially manufactured articles would be immaterial.

It has appeared from these studies that in order to prevent damage to a string of insulators subjected to accidental flash-over, the following points of design should be adhered to:

1. The voltage gradient along the string from conductor to grounded support should gradually decrease.

2. A shield ring should surround the No. 1 unit so proportioned that even under rain conditions discharge will start from it rather than from the hardware of the first unit. The ring should be complete so as to permit an arc to travel round it without crossing into the string.

3. The cross-sectional shape of the ring should be such that an arc-over produced by sufficiently high voltage will start from a part of the ring where the field of force, or flux, is strongly divergent from the insulator string, thus forcing the arc well out and away from the insulators. The point of origin of the arc-over

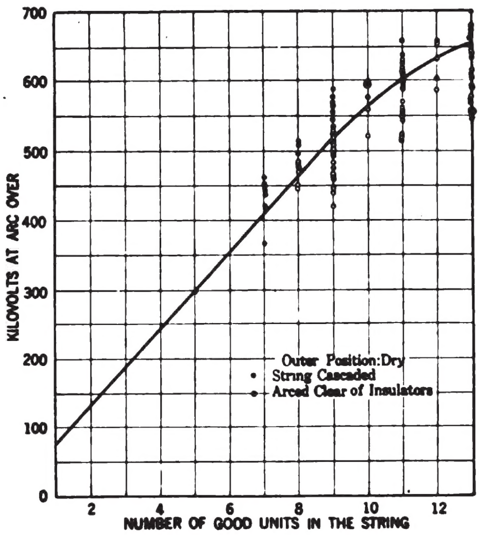


Fig. 20

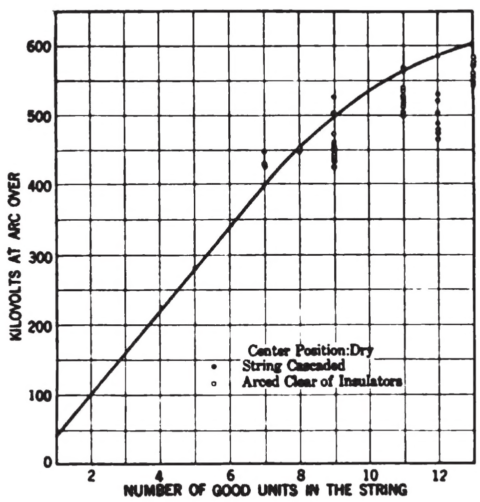


Fig. 21

Fig. 20 and 21—Summary of Arc-Over Tests at 60 Cycles of Suspension Strings with and without Shields
Characteristic cascading curves—Locke No. 5996 insulator in Big Creek tower.
Tests at Pittsfield.

but by a proper proportioning of the shield ring the first three or four units can be prevented from cascading, the initial discharge taking place from the ring to the cap of No. 3 or No. 4 unit and then cascading the rest of the string. With sufficient power behind the arc, it will almost instantly leave the insulator

is controlled by the radius of curvature of the cross-section of the ring in its various parts.

4. A top shield ring is advisable both to prevent an increase in voltage gradient over the upper third of the string and also to allow of the arc traveling around clear of the porcelain.

Field Tests

After the conclusion of the laboratory tests a portion of the West Big Creek line, 27 miles in length, was cut out of regular service, and equipped for high-voltage testing on a scale approximating more to actual service conditions than could be obtained in any laboratory. Some account of the results has appeared in the *Electrical World* of February 11th, 1922, with a corrected table of coefficients in the May 6th number.

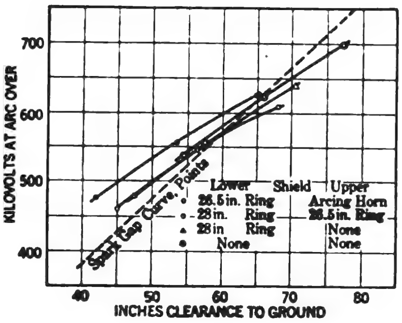


Fig. 22—Relation between Clearance to Ground and Arc-Over Voltage at 60 Cycles

For the sake of convenience and easier reference some of the substance of the article will be included here.

The purpose of the tests was to obtain:

1. Measurements of corona loss under such atmospheric conditions as might occur, and the determination therefrom of constants for weathered aluminum cables of large size.

2. A determination of the charging current of a line equipped with shielding devices and a comparison with calculated values.

3. A study of insulation.

4. Miscellaneous data.

The physical constants of the line are:

Conductors: Steel core aluminum, core 7-strand 78,500 cir. mils; aluminum strand 605,000 cir. mils; diameter 0.96 in.; horizontal construction, spacing 17 ft. 3 in.; average height above ground 33 ft.

Ground Wire: ½-in. steel 7-strand cable.

Towers: Structural steel.

Insulators: Cap and pin standard 10-in. suspension.

Transpositions: None.

At first two insulators were added only to those suspension strings where not less than normal clearance to ground would remain after so doing, this resulted in there being:

249 Suspension strings of 9 units.

42 Suspension strings of 11 units.

348 Dead-end strings of double 13 units.

48 Tie-down strings of one more unit than the corresponding suspension.

The shield ring was of a slightly different design from the one that will be used for the conversion of the complete lines but had practically the same electrical characteristics.

It had developed in laboratory tests that an arc-over in the central position of the tower would most frequently ignore the arcing horns at the top of the insulator string and go to the cap of the top unit. It was feared that this would endanger this unit and possibly some below it, so a lighter type of shield ring was installed around the top unit of all center position strings. In the outer positions the tower structure does not so effectively shield the arcing horns, and flash-overs go to them. No upper ring was put there and the arcing horns were left in position.

The lower end of all suspensions had shield rings, as had the line ends of dead-end strings, horns being left at the tower ends of these latter.

Tie-down strings had rings around their top units, the rings being similar to those used at the top of center suspensions.

The line was energized from three 4500-kv-a. 150,000/72,000-volt transformers, having various taps, connected in star on the high side with neutral grounded. For the first tests the low side was connected in star on the 36,000-volt tap and fed from the 64,000-volt (nominal) bus at Eagle Rock substation.

Corona Loss. Realizing that for the results to have any value, fairly accurate measurements of voltage and power would be necessary, some care was taken in the selection and calibration of instruments.

For the measurement of voltage, taps were brought out from the high-tension winding of each transformer near the grounded end and the ratio determined of the voltage from tap to ground compared with the voltage across the whole high-tension winding. This was found to be 7.1 kv. to 150 kv. The tap voltage was measured in service through 200-watt, 11,000/110-volt potential transformers whose only other load was the potential coils of Weston wattmeters.

The voltage between phases was found to be well balanced so that ordinarily the voltage from only one conductor to ground was read and recorded.

The load upon the energizing bank of transformers not exceeding 7 per cent in kilowatts of their rated capacity and being practically constant in kilovolt-amperes, voltage readings were taken off the low side of the transformers through potential transformers for many of the tests, the proper ratio being determined by comparison with readings on the voltage tap on the high side. The rise of voltage along the line was calculated not to exceed 0.3 kv. and was neglected.

Readings were taken regularly by the switchboard attendants to the nearest 0.5 volt on the meter, corresponding to 1.25 kv. on the line. This lack of precision was to some extent compensated for by the number of readings, a reading being taken every two hours except in rainy weather when hourly records were kept.

Power delivered to the line was measured by three Weston laboratory wattmeters calibrated, down to a power factor of 0.04 leading, against a standard in the laboratory of the Southern California Edison Company, these standards having been previously checked by the Bureau of Standards. Checks were also made against oscillograph records as detailed later.

When tests were first planned it was hoped that the losses on each conductor would be determined separately; the effect of the different capacities between pairs of conductors due to the three conductors being in a horizontal plane and conductors and ground, there being no transpositions in the line, was overlooked. The effect of these capacities is illustrated in Fig. 23 where *A G, B G, C G* are the conductor voltages to ground and *A B, B C, C A, B A, B C, A C* are voltages, between conductors representing the relative times at which the first letter becomes a positive maximum to the second.

Assume first that there are no losses. Consider the conductor *A* one of the outer conductors; its charging current, considered as a condenser to ground is I_{AG}. There is also the condenser formed by conductors *A* and *B* and and *A* and *C* respectively, *C* being the center conductor. These have charging currents I_{AB} and I_{AC} the resultant line charging current being I_A. On account of the capacity *A C* exceeding that of *A B* the current I_A is displaced more than 90 degrees ahead of the voltage *A G*. The wattmeter fed by *A G* and I_A therefore reads backward when connected normally. For similar reasons wattmeter *B* reads forward and wattmeter *C* reads zero, with a circuit symmetrical about conductor *C* the sum of the wattmeter readings is zero.

The effect of losses in the circuits is to reduce the negative reading of wattmeter *A* finally rendering it positive in increasing degree as the loss increases. Both *B* and *C* wattmeters read positive with increase of losses, the sum of the three readings being the total power. Some considerable knowledge of the various circuit capacities is therefore required before the losses upon individual conductors can be determined. In the present case, including as it does three conductors and a ground wire on the one tower line and a similar adjacent line, the currents and voltages in the two lines having various phase displacements, and the capacities varying to some extent with the corona, the mathematical solution becomes complicated.

As a further check upon instrumental and systemic errors the instrument potential transformers were interchanged, wattmeters were interchanged, phase rotation upon the low side of the energizing transformers was changed, each of these changes being made singly at a time, no readable change in losses was effected by interchange of wattmeters or potential transformers.

The effect of changing rotation is given in Table I.

TABLE I
Effect of Phase Rotation upon Wattmeter Readings

Conductor Phase	West *C*	Center *B*	East *A*	Sum of wattmeters
Wattmeter reading..........	− 6.0	+ 0.5	+ 6.5	1.0
Phase.....................	*A*	*B*	*C*	
Wattmeter reading..........	+ 6.0	0	− 6.0	0.0

The positive and negative readings interchange with the phase interchange in accordance with the vector diagram Fig. 23. The difference of 1.0 in the sum of the readings is equivalent to 0.33 kw. per mile of conductor; the readings were necessarily taken some hours apart.

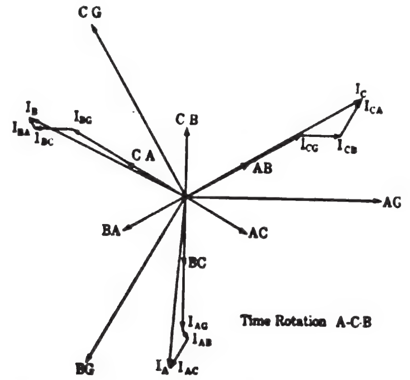


Fig. 23—Vector Diagram of Currents and Voltages when Metering Corona Losses

The magnitude of the effect of induction from the parallel line was determined roughly by energizing the test line from a separate generator, at a slightly lower frequency than obtained on the paralleling lines. As the phase relation between the two lines changed, the wattmeter readings oscillated between minimum and maximum readings. The extent of the oscillation is given in Table II as follows:

TABLE II
Test for Induction from Parallel Line

Phase	*C* Wattmeter reading	Amperes	*B* Wattmeter reading	Amperes	*A* Wattmeter reading	Amperes	*A* Kv. to neutral
Min.....	− 4.2	15.5	− 0.2	16.9	3.0	15.0	124.6
Max.....	− 5.0	15.6	+ 0.2	17.2	6.0	15.8	124.6
Min.....	− 5.2	17.1	− 0.4	18.8	4.2	16.8	137.8
Max.....	− 5.9	17.2	+ 0.2	19.0	7.2	17.4	137.3

The larger swings of the *A* wattmeter are due to its being undamped. Both *C* and *B* wattmeters had well damped movements. The period of the swings was of the order of one or two per second. The maximum and minimum readings were not simultaneous in the three meters and it is felt that the effect of the parallel circuit upon the sum of the three readings was very small.

The practical requirement was to determine the total losses and this is given correctly by the sum of the three wattmeter readings.

The sensitiveness of the wattmeters was such that the sum of the three scale division readings multiplied by 26.4 gave the total loss in kilowatts; the routine readings were taken to the nearest half a scale division.

The relative readings of the three wattmeters is shown in Figs. 24 and 25, which indicate that the variations are according to the theory of the vector diagram Fig. 23.

As a still further check upon the wattmeters, though it was only a rough one, oscillograph records of voltage and current were taken simultaneously with wattmeter readings and the curves analyzed, by the eighteen-ordinate method, the results being as follows:

Phase A

Voltage in kv.:

$200.3 \sin (P\,t - 359° 43') + 1.31 \sin (3\,P\,t - 168° 13')$
$+ 3.12 \sin (5\,P\,t - 177° 59') + 0.16 \sin (7\,P\,t - 135° 0\,0')$
$+ 0.27 \sin (9\,P\,t - 68° 10') + 0.38 \sin (11\,P\,t - 123° 40')$
$+ 0.16 \sin (13\,P\,t - 71° 33') + 0.27 \sin (15\,P\,t - 101° 19')$
$+ 0.11 \sin (17\,P\,t - 63° 25')$

Current in amperes:

$24.82 \sin (P\,t - 274° 29') + 0.19 \sin (3\,P\,t - 339° 27')$
$+ 2.44 \sin (5\,P\,t - 86° 59') + 0.16 \sin (7\,P\,t - 99° 17')$
$+ 0.27 \sin (9\,P\,t - 89° 57') + 0.38 \sin (11\,P\,t - 351° 02')$
$+ 0.16 \sin (13\,P\,t - 231° 20') + 0.27 \sin (15\,P\,t - 101° 19')$
$+ 0.11 \sin (17\,P\,t - 189° 28')$

Power calculated from the above . . . . .206.3 kw.
Power measured 7.3 $\times$ 26.4 . . . . =192.7 kw.

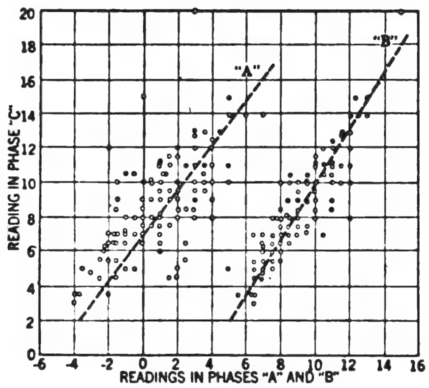


FIG. 24—RELATION OF THREE WATTMETER READINGS, 19.5-MILE TEST AT 161 KV. TO NEUTRAL

This is considered a satisfactory agreement when the difficulty of measuring oscillograph curves and the smallness of the wattmeter reading are taken into account.

$I^2 R$ losses in the transformer high-tension windings and line conductors were calculated.

From Peek's formula, after substituting the physical constants of the line; the logarithmic mean of the three conductor spacings being used:

$$P = \frac{0.01263}{\delta} (e - e_0)^2, \quad \text{also}$$

$$e_0 = 162.2\,\delta\,M_0 \quad ; \quad \text{whence}$$

$$M_0 = \frac{e - \sqrt{\dfrac{P\,\delta}{0.01263}}}{162.2\,\delta}$$

where M_0 = Surface irregularity factor and used here to include weather effects including storm
e = Voltage to neutral in kv.
P = Average kw. loss per mile per conductor
δ = Air density coefficient.

By the above formula each hourly and two-hourly observation was calculated and the corresponding value of M_0 found that would satisfy the quadratic equation of loss.

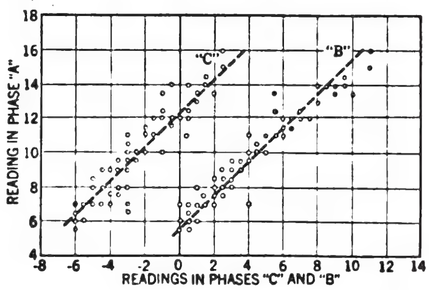


FIG. 25—RELATION OF THREE WATTMETER READINGS, 27-MILE TEST AT 141 KV. TO NEUTRAL

The line was energized at around 161 kv. to neutral from Sept. 16th, 1921, to Oct. 15th, 1921, when it was decided to lower the voltage to about 140 kv. to neutral. This was done for two reasons; the noise of the line at 161 kv. to neutral was annoying to property holders, and it was felt that data should be collected at a voltage

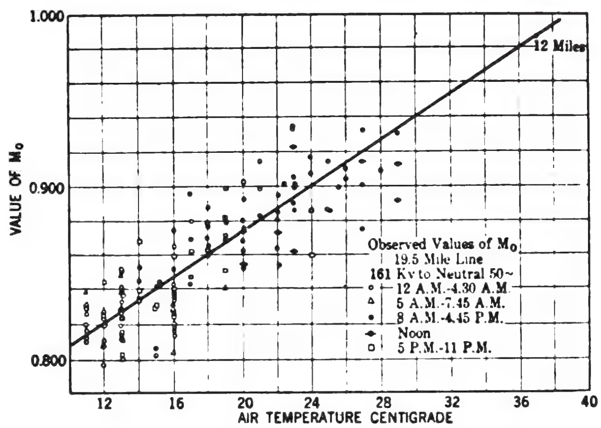


FIG. 26—VALUES OF IRREGULARITY FACTOR CALCULATED FROM OBSERVATIONS IN RAINLESS WEATHER

nearer that at which commercial operation was going to be undertaken.

The selection of 140 kv. was made because its excess above the critical disruptive voltage on the test line was approximately the same as would exist with commercial 127 kv. to neutral at the points of highest altitude of the whole line. Data from the test line, at an average elevation of 1500 feet, would therefore correspond to commercial conditions at 220 kv. between conductors at between 4000 and 5000 feet. At 140 kv. to neutral the line was almost noiseless so that that voltage was suitable in all respects.

TABLE III
Daily Average Storm Losses at 141 kv. to Neutral

Date	No. of hours	Loss Kw-hr.	P Loss per conductor per mile	Temp. deg. cent.	Bar. cm.	$e - e_0$	Kv. to neutral e	Critical voltage e_0	Factor M_0
10/20	8	143	0.221	26	71.7	4.1	141.3	137.2	0.900
21	24	1191	0.612	19	71.7	6.8	140.0	133.2	0.853
22	24	1193	0.613	17	71.9	6.9	140.5	133.6	0.847
23	12	846	0.870	12	72.0	8.3	141.6	133.3	0.829
24	20	384	0.237	12	72.3	4.3	141.2	136.9	0.849
11/14	5	183	0.489	14	72.3	6.2	142.3	136.1	0.849
15	18	584	0.401	13	71.7	5.6	141.5	135.9	0.853
25	6	396	0.815	5	72.5	8.1	142.1	134.0	0.810
12/17	16	546	0.420	12	72.2	5.7	142.2	136.5	0.848
18	24	6452	3.34	10	71.7	16.2	143.3	127.1	0.789
19	24	11990	6.17	11	72.0	22.0	141.1	119.1	0.739
20	24	7285	3.75	13	72.1	17.1	139.5	122.4	0.764
21	24	2913	1.50	11	72.1	10.9	139.3	128.4	0.796
22	24	2827	1.45	7	71.7	10.7	140.1	129.4	0.796
25	24	3136	1.61	10	72.1	11.3	137.3	126.0	0.779
26	14	2127	1.87	12	72.1	12.1	138.1	126.0	0.783
27	15	2733	2.25	13	72.5	13.3	139.8	126.5	0.785
1/1	22	5303	2.98	14	71.8	15.2	139.0	123.8	0.778
2	14	2653	2.34	10	71.5	13.5	138.8	125.3	0.780
6	17	1683	1.22	6	72.3	9.9	143.6	133.7	0.810
29	24	4885	2.51	2	71.6	14.3	140.1	125.8	0.759
30	24	3690	1.90	5	71.5	12.3	142.2	129.9	0.795
31	12	1056	1.09	3	72.1	9.4	141.8	132.4	0.797
2/8	20	3980	2.46	10	72.2	14.0	142.6	128.6	0.792
9	22	2804	1.57	11	72.4	11.2	141.7	130.5	0.805
10	12	471	.48	11	72.5	6.2	140.2	134.0	0.826
11	24	3158	1.62	10	72.5	11.3	139.7	128.4	0.789
Total	497	74.612							
Average			1.853				140.8	128.9	

The results for the test upon 19½ miles of line at about 161 kv. to neutral are plotted in Fig. 26, including one observation upon 12 miles of line at a high temperature.

It will be noted that there is apparently a relation between M_0, and consequently the loss in the line, and temperature, which is not accounted for by the Peek formula. Observations taken during different periods

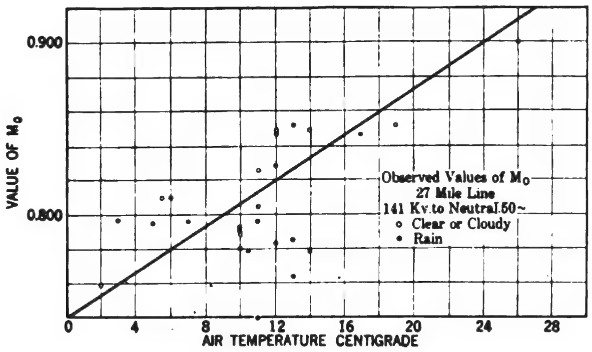


FIG. 27—VALUES OF IRREGULARITY FACTOR CALCULATED FROM OBSERVATIONS IN RAINY WEATHER

of the day are distinguished in the chart with the object of determining whether variations of load in the adjacent power-carrying line were responsible for the variations in M_0 apparently however they are not.

These observations were made during all kinds of weather with the exception of rain or snow, but include clear, cloudy, heavy fog, and misty conditions.

The value of M_0 does not seem to depend much upon such conditions but varies mainly with temperature, and for the particular conductor experimented upon is given by

$$M_0 = 0.00667\,(t + 111)$$

Where t = deg. cent.

In clear weather no loss was measurable at 140 kv. to neutral, the voltage was quite close to the critical point as a loss of some few tenths of a kilowatt per mile per conductor occurred in cool cloudy weather.

Storm losses are given in Table III as average quantities taken over each day, the relation these bear to the annual average can be gaged by the total precipitation during the period registered at Los Angeles which was 12.60 inches as compared with the annual average of 15.6 inches.

The plot of M_0 with temperature is in Fig. 27, the drawn line being the line of Fig. 26 produced.

The lowest values of M_0 observed occurred during the storms of Dec. 19, 1921 and Jan. 29, 1922. On Dec. 19th a total precipitation of 3.28 inches for the twenty-four hours was recorded at the Weather Bureau's station at San Fernando, close to the line, and not far from the middle of its length, and otherwise having climatic conditions averaging those along the length of the line.

Hourly readings for this day are given in Table IV and indicate the value of M_0 to be expected under heavy precipitation.

During the storm of January 29, 1922, a snow storm covered part of the line for a short time at noon, the precipitation recorded in Los Angeles for the hours 11 a. m. to noon being 0.52 inch. The losses and constants for the four hours of heaviest loss are given in Table V.

Of interest is the effect upon losses of suddenly energizing an idle line during stormy weather. This was done during a rain storm, the line having been dead for an hour. The readings, which were of only

TABLE IV
Hourly Storm Losses Dec. 19, 1921 at 141 Kv. to Neutral

Time a. m.	Loss per conductor per mile P	Temp. deg. cent.	Bar. cm.	$e - e_0$	Kv. to neutral e	Critical voltage e_0	Factor M_0
12:05	5.77	10	71.7	21.3	141.6	120.3	0.747
1:05	2.84	10	71.7	14.9	142.6	127.7	0.793
2:05	3.65	10	71.7	16.9	141.6	124.7	0.775
3:10	4.31	10	71.7	18.4	141.6	123.2	0.765
4:03	7.08	10	71.6	23.6	141.6	118.0	0.734
5:10	7.23	10	71.7	23.8	140.5	116.7	0.725
6:05	6.92	10.5	71.8	23.3	140.5	117.2	0.731
7:10	8.05	10.5	71.8	25.1	139.5	114.4	0.714
8:20	6.26	10.5	71.9	22.1	140.5	118.4	0.737
9:00	7.89	11	71.9	24.9	141.6	116.7	0.725
10:15	9.03	11	71.9	26.6	141.6	115.0	0.715
11:07	9.36	11	71.9	27.1	141.6	114.5	0.712
12:05	8.05	11	71.9	25.1	142.6	117.5	0.731
1:15	7.72	11	71.9	24.6	142.6	118.0	0.733
3:00	4.47	11	72.0	18.8	141.6	122.8	0.762
4:10	3.81	11	72.1	17.3	139.4	122.1	0.756
7:10	2.35	11	72.1	13.6	139.4	125.8	0.780
8:10	4.85	11	72.2	19.5	141.6	122.1	0.756
9:10	3.65	11	72.2	12.3	143.7	131.4	0.813
10:20	7.31	11	72.2	24.0	139.4	115.4	0.715
11:10	3.65	11	72.2	17.0	139.4	122.4	0.758
12:20	4.31	11	72.2	18.4	137.3	118.9	0.736

relative value, were taken on the switchboard indicating wattmeter measuring total input to the low side of the energizing transformers and the following readings obtained:

Upon another occasion a reading as high as 2500 kw.

TABLE V
Storm Loss Jan. 29, 1922

Time a. m.	P	Deg. cent.	Bar cm.	$e - e_0$	e	e_0	M_0	Weather
10:15	7.89	6	71.5	25.1	139.4	114.3	0.701	Rain
11:00	7.85	6	71.4	25.0	139.4	114.4	0.703	Rain
12:00	8.05	6	71.3	25.3	139.4	114.1	0.702	Snow
1:00	6.26	6	71.2	22.3	139.4	117.1	0 722	Rain

was obtained on first energizing the line after it had been idle for an hour in a rain storm, it being remembered that transformer losses are included.

It is not known where the extreme loss occurs but most probably it is over insulator surfaces.

TABLE VI
Initial Loss on Energizing Line

Time after closing switch	Wattmeter reading kw.
0	1150
15 seconds	700
30 "	500
45 "	400
1 minute	350
2 "	300

The rapid decrease of loss with time shows to what extent the line and insulators dry themselves under the influence of leakage current. The quickness of the drying—a 50 per cent reduction of loss in 30 seconds—would indicate that there is not much to fear from strange voltage distribution effects upon insulators due to ordinary rain storms, as the effect of leakage current is to remedy the trouble; furthermore, the effect of wet surfaces is to increase the capacity of the insulators and produce a more even voltage distribution between them. The wave shape of the impressed voltage upon

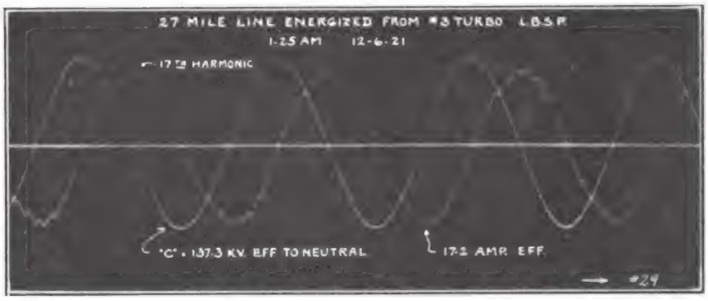


FIG. 28—CHARGING CURRENT OF EXPERIMENTAL LINE

the line for the two series of routine tests was approximately as follows:

Series at	161 kv.	140 kv.
Fundamental amplitude......	100.00	100.00
Third harmonic.............	0.66	0.65
Fifth "	3.62	1.56
Seventh "	0.99	0.08
9th to 17th "	Less than 0.4	Less than 0.2

In addition to the continuous routine tests at approximately constant voltages a test on variable voltage was run on Oct. 12, 1921.

The line was energized over connections separate from the general system from a 15,000-kv-a. Curtis steam turbo-generator. The voltage wave shape was extremely close to a sine as evidenced by the wave shape of charging current of the line which showed only ripples of the 17th harmonic, see Fig. 28.

TABLE VII
Corona Test of 19½ Mile Line

			Temperature 11° C			Bar. 72.0 cm.		
Time a. m.	Kv. to neutral	Kw. total loss	Kw. $I^2 R$	Corona loss kw.	Loss per conductor per mile	$- e_0$	e_0	M_0
12:50	124.6	26.4	8.8	17.6	0.301	4.9	119.7	0.743
1:05	116.2	0	7.3	..	..	..	..	..
1:20	133.1	13.2	10.1	3.1	0.053	2.04	131.0	0.813
1:30	139.4	66.0	11.4	54.6	0.934	8.57	130.8	0.812
1:43	147.9	118.8	12.5	106.3	1.818	11.97	135.9	0.844
1:55	155.5	264.0	14.0	250.0	4.275	18.34	137.2	0.851
2:05	158.5	356.3	14.8	341.5	5.840	21.45	137.1	0.850

The results are given in Table VII. Visual corona in the span between towers was not in evidence at 139.4 kv. but was plainly noticeable at 147.9 kv. The visual corona point is somewhere between these two values.

The value of M_0 calculated from this test is higher than would be in accord with the data of Fig. 27 at a temperature of 11 deg. cent. This is to be expected from the better wave shape of voltage used in the test

of Oct. 12th. Assuming 146 kv. to be the critical visual point, the value of M_v, the visual irregularity factor can be calculated from Peek's formula.

$$e_v = 21.1\, M_v\, \delta\, r \left(1 + \frac{0.301}{\sqrt{\delta\, r}}\right) \log_e s/r$$

whence for the constant of the line
$M_v = 0.713$

TABLE VIII
Single-Phase and Three-Phase Corona Test
Date Jan. 3. 1922

Time a. m.	Kv. to neutral	Loss kw.	Charging current amperes	Circuit arrangement
8:10	140.5	26.4	18.1	Average Three-phase
11:00	142.0	13.2	18.5	Single-phase with idle conductor insulated.
11:22	141.2	13.2	18.5	
11:40	141.6	2.6	18.4	Single-phase with idle conductor grounded.
12:10	139.5	5.2	18.35	
12:15	141.2	10.4	18.5	
5:00 p. m.	142.6	0	18.0	Three-phase

Different observers' ideas upon visual corona differ so that this value may be considered in good accord with Peek's value of 0.72 for local corona.

To substantiate the form of the formula, which makes the corona loss dependent upon the voltage to neutral and not upon voltage between conductors, two of the energizing transformers were reconnected, with low

TABLE IX
Corona Loss at 127 Kv. to Neutral
Fair Weather

Altitude ft.	Temp. deg. cent.	Bar. cm.	δ	M_0	e_0	$e - e_0$	P
0	25						
500	25	74.8	0.984	0.900	143.6	..	..
1000	25	73.3	0.964	0.900	140.7	..	..
2000	25	70.6	0.929	0.900	135.6	..	..
3000	25	67.9	0.893	0.900	130.4	..	..
4000	25	65.4	0.860	0.900	125.5	1.5	0.03305
4500	25	64.2	0.844	0.900	123.2	3.8	0.2160
5000	25	63.0	0.829	0.900	121.0	6.0	0.5485
			Heavy Storm				
500	10	74.0	1.025	0.710	118.1	8.9	0.976
1000	10	72.5	1.004	0.710	115.7	11.3	1.605
2000	10	70.0	0.970	0.710	111.7	15.3	3.048
3000	5	67.0	0.931	0.660	99.7	27.3	10.11
4000	0	65.0	0.934	0.650	98.4	28.6	14.92
5000	− 5	62.5	0.914	0.600	89.0	38.0	19.95
Average taken over whole length of line							3.46
			Average Storm				
500	10	74.0	1.025	0.800	133.1	..	..
1000	10	72.5	1.004	0.800	130.4	..	..
2000	10	70.0	0.970	0.800	125.9	1.1	0.0156
3000	5	67.0	0.931	0.774	116.9	10.1	1.384
4000	0	65.0	0.934	0.740	112.1	14.9	3.002
5000	− 5	62.5	0.914	0.706	104.6	22.4	6.930

sides in parallel on the same phases and high sides in series, middle point grounded, single and three-phase losses could be then compared, there being the same voltage to neutral in each case, as follows in Table VIII:

In both three-phase and single-phase tests the voltage to neutral was only slightly above the critical disruptive point with only negligible losses in consequence. Had the voltage between conductors been the determining factor the single-phase loss with 283 kv. would have greatly exceeded the three-phase loss at 245 kv.

Corona Losses on Line at 220 Kv.

From the various data accumulated it has been possible to estimate what the average annual loss from corona will be upon the two complete lines. There

TABLE X
Annual Kw-hr. Corona Losses at 127 Kv. to Neutral

Altitude feet	Precipitation inches	Annual loss per conductor per mile Kw-hr.
2000	20	10
3000	25	1114
4000	30	2898
5000	35	7805

being considerable variations in altitude above sea level, losses have been calculated for different elevations at average temperatures for fair weather, heavy storm and average storm. The values of M_0 assumed for different weathers and temperatures are believed to be conservative. The resulting loss P in kw. per conductor per mile are given in Table IX.

The kw-hr. loss per annum involves not only the magnitude of storm losses but the duration of the same.

For want of a better method it has been assumed that these losses will be directly proportional to the annual precipitation in any locality. This is based primarily upon the observed data on the test line where

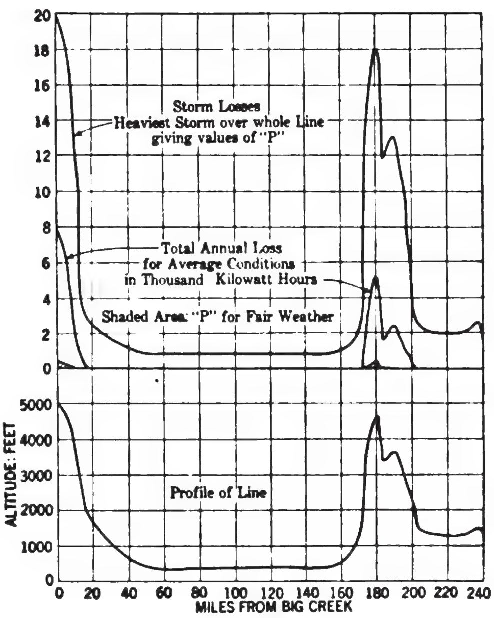


Fig. 29—Profile of Big Creek Line and Corona Losses

a total loss of approximately 74,600 kw-hr. occurred upon 81 miles of single conductor during an average precipitation upon the line of 15.47 inches, or at the rate of 4820 kw-hr. per inch. From Table III it is seen that this rate of loss corresponded to an average loss per conductor per mile of P = 1.85.

Expressing the annual kw-hr. loss per conductor per mile = P_a then

$$P_a = \frac{74{,}600 \times P \times P}{81 \times 15.47 \times 1.85} = 32.2\, P \times p$$

P is the average storm loss at any altitude as given in Table IX. p = Annual precipitation in inches.

Applying appropriate precipitation data, Table X is obtained, giving annual kw-hr. losses at different altitudes.

Fig. 29 gives an approximate profile of the Big Creek lines together with the constants of Tables IX and X applied to it.

Fair weather losses occur only at 4000 ft. and above and are entirely negligible. The heaviest storm losses are plotted assuming the whole length of the line to be simultaneously involved which is practically impossible. However, under this extreme assumption the maximum loss, obtained by integrating the loss curve amounts only to 5000 kw. total for both lines; 2.08 per cent of their rated carrying capacity.

TABLE XI
Charging Current of Line Equipped with Shield Rings
Line Energized from System

Length of line miles	Voltage to neutral kv.	Changing current amperes			Avg.	Calculated	Measured in per cent of calculated
		A	C	B			
7	157.1	5.0	5.8	5.2	5.33	4.865	109.5
12	158.65	8.8	9.7	9.0	9.17	8.425	108.8
19.5	160.7	15.0	16.0	14.6	15.20	13.87	109.6
27	140.9	17.98	18.92	17.59	18.16	16.84	107.8
27	141.0	17.96	18.94	17.75	18.21	16.85	108.1

The annual loss shown by another curve in the same figure totals 780,000 kw-hr. At a 50 per cent load factor the load transmitted over the lines will be of the order 1,000,000,000 kw-hr. per annum. The average corona loss is therefore about 0.08 of 1 per cent and at higher load factors becomes correspondingly less.

Practically all of this loss will occur in a distance of 44 miles. Moderate enlargement of the conductor from a diameter of 0.96 in. to 1.05 in. and 1.10 in. according to elevation would eliminate this small loss.

Charging Currents

The charging current of the line was measured by Weston ammeters having 25-ampere scales. The meters were connected directly in the grounded end of the transformer high-tension windings. They were correct to within less than 0.1 ampere.

The calculated current is based upon the logarithmic mean spacing of the conductors and exact hyperbolic formula, inductance being

$$L = 0.741 \log \frac{S}{r} + 0.304 \text{ millihenries per mile to neutral}$$

and capacity given by

$$C = \frac{0.0388}{\log \dfrac{S - r}{r}} \text{ microfarad per mile.}$$

In the 7- 12- and 19.5-mile tests $Y\,Y$ connected transformers energized the line and the voltage wave shape is responsible for about 2 per cent increase in current, leaving on an average 7.3 per cent increase over the calculated. In the 27-mile test with delta-star transformers the wave shape was more nearly sinusoidal and but 0.8 per cent increase is due to harmonics leaving a final increase of 7.1 per cent. The average for the test upon a separate turbine with practically pure sine wave of voltage gives 7.6 per cent more than the calculated current.

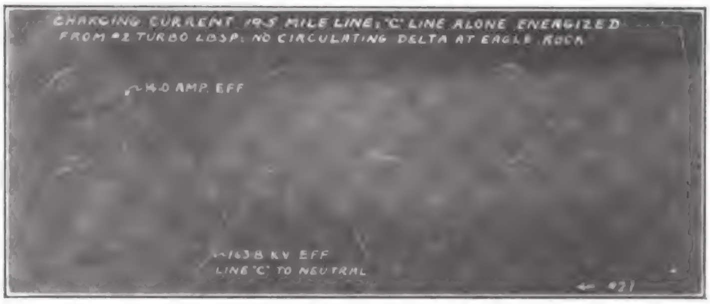


FIG. 30—CHARGING CURRENT OF A SINGLE CONDUCTOR

It can therefore safely be said that the shield rings that will be used, together with the effect of other hardware, insulators, ground wire and adjacent parallel line, will cause an increase in charging current of about 7½ per cent above values calculated from the mean logarithmic spacing of the conductors by the above noted formulas.

TABLE XII
Charging Currents at 159.5 Kv. to Ground
19.5 miles of line

Phase	A	C	B
Three-Phase	14.80	15.50	15.10
Two Conductors	14.44	Out	13.6
	Out	14.20	14.30
	13.94	14.69	Out
One Conductor	13.78	Out	Out
	Out	14.40	Out
	Out	Out	14.08

A comparison of the charging current with either one, two or three conductors energized, the idle conductors being insulated from ground, is as follows, the voltage to neutral being the same in each case:

These values of charging current are not directly comparable with each other due to wave distortion when only one and two conductors are energized. They have a practical bearing upon what happens when switch contacts fail to operate simultaneously. Oscillogram Fig. 30 shows the distortion.

Residual Current to Ground

The residual current to ground from the neutral connection of the transformers increases with the volt-

age. With delta connections such as will be provided by auto-transformer tertiaries the residual will be chiefly a fifth harmonic superimposed upon a fundamental of induction from the parallel second circuit.

The fundamental can be greatly reduced by having the proper phase relation between the two circuits, the best relation giving only approximately one-half the current, that will flow when the relative phase relations are most unsuitable.

Neither the test line nor the paralleling power line was transposed; transpositions will greatly reduce residuals and will be put in both lines before operating at 220 kv.

Peek has showed that grounding the line through transformer neutrals at several points along its length also reduces the residual. The Big Creek lines will be grounded at both ends and the middle, and no trouble from ground currents is expected to arise.

Insulation

As the work of installing shields upon the line progressed additional sections were energized.

Sept. 16, 1921	7	miles	of	line	were	energized	at 275 kv.
Sept. 27, 1921	12	"	"	"	"	"	" 277 "
Sept. 30, 1921	19.5	"	"	"	"	"	" 280 "
Oct. 20, 1921	27	"	"	"	"	"	" 241 "

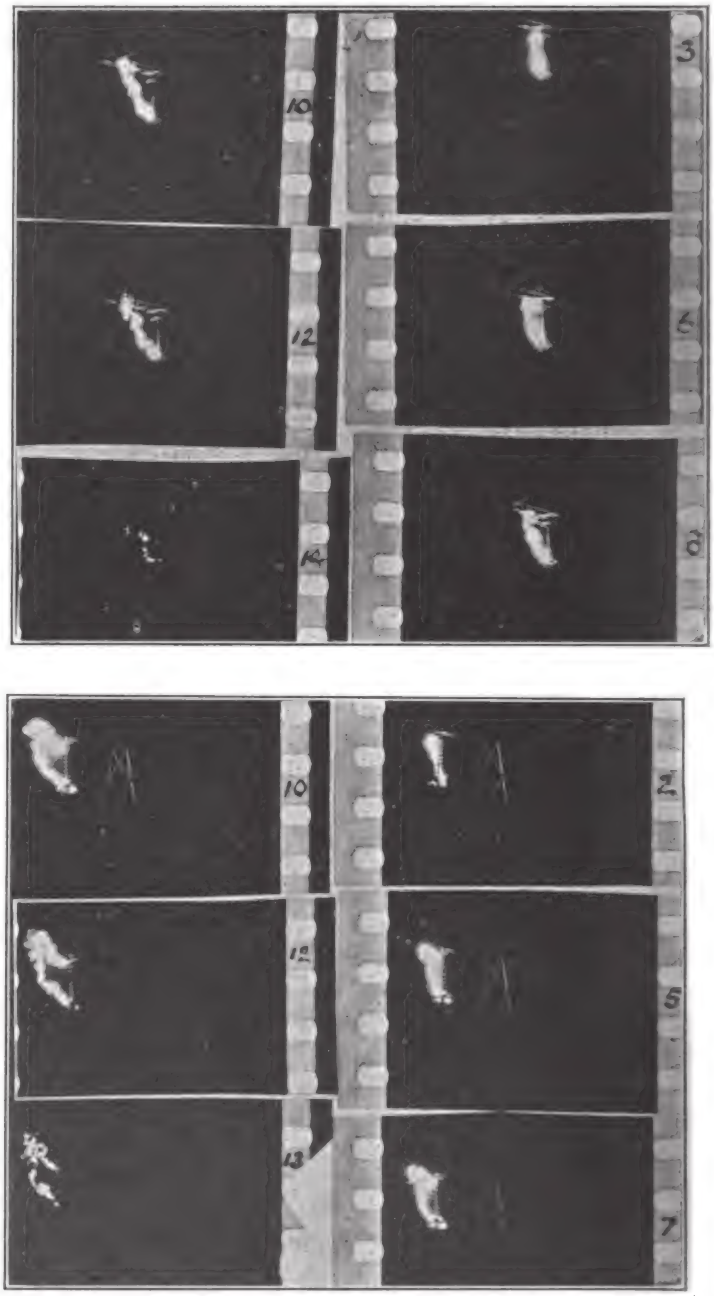
During the above time and up to Nov. 25th, 85.6 per cent of the suspension strings had 9 units, the remainder 11 units each, standard 10-in. suspension disks of cap and pin type being used throughout.

From Nov. 25, 1921 to Dec. 4, 1921 the line was out of service while additional insulators were installed, bringing all suspension strings up to eleven units each.

The line remained energized until Feb. 16, 1922 when the test had to be discontinued as the energizing transformers could no longer be spared for the purpose.

The first rain of the season came Sept 30, 1921, starting with gentle showers and mist and continuing thus intermittently throughout the day. At 8.52 p. m. the relays upon the 65-kv. side of the transformers cut the line out of service. The line was not put back into service until noon of the following day when it was switched onto the system at full voltage during the rain. No further trouble developed, but two or three days later, the cause of the trouble on the 30th was found by the patrolman to be a nine-unit suspension string which had arced over under about 161 kv. to ground. The arc-over was typical, having followed an identical path to that observed in laboratory flash-overs under artificial rain. It originated on the lower shield ring, then jumped to the cap of the No. 3 unit, then to No. 4, then jumped clear to No. 7 cap and cascaded both No. 8 and No. 9. The porcelain of the top No. 9 unit was cracked off on one side. This string with eight good remaining units went back into service in the rain and stood up until changed some days later. This was the only failure of insulation while the line was energized at 280 kv. It occurred under the most trying climatic conditions of the first rains, upon insulators covered with the accumulated dirt and dust of the whole preceding dry season.

During operation at 245 kv. the line kicked out on Nov. 6, 1921 and Jan. 18, 1922 without apparent reason in clear weather. The line was most carefully patrolled but no evidences of flash-over discovered. Later after the test was all over and the transformers were being put into normal service at 150 kv. one of them broke down and upon opening up the coils it was found that surface discharges across insulating barriers had taken place under the oil. There is no proof that this was the cause of the unexplained cutting out of the line but it seems probable.



Figs. 31 and 32—Successive Stages of Arc-Overs on Line

With a view to observing the action of the insulation with its shields under arc-over, with more energy in the arc than was obtainable in the laboratory, intentional arc-overs were made by pulling a No. 40 copper wire across the insulator. Both still and motion pictures were taken of the arc which behaved entirely similarly to laboratory arcs with the exception that the light was vastly greater.

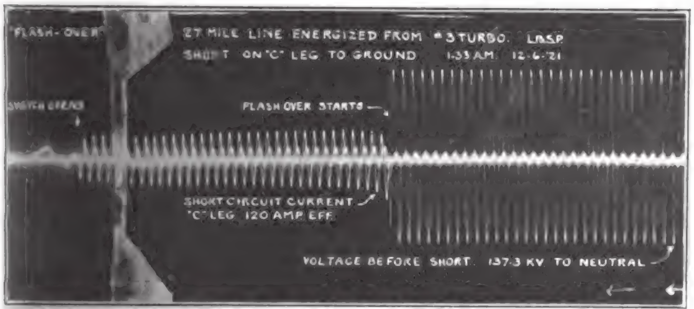


Fig. 33—Current During Arc-Over on Tower

For these flash-overs the line was fed from a 25,000-kv-a. steam turbine. The current in the arc was approximately 120 amperes. Fig. 31 shows progressive stages of an arc in the center position of the tower and Fig. 32 shows similar stages of an arc in the outer position. It is interesting to note the dying out of the arc in patches of incandescent vapor. These arcs lasted about 32 cycles, the relay then opening the circuit. No damage was done to porcelain or hardware. Fig. 33 gives the oscillogram of the performance; gradual decrease in the current is noticeable as the arc lengthens.

Air-Break Switch

Some experimental work was done toward developing an expensive air-break switch for line sectionalizing. To settle the question as to whether such a switch would be able to break the charging current of a 27-mile length of line, one was set up in the line and opened.

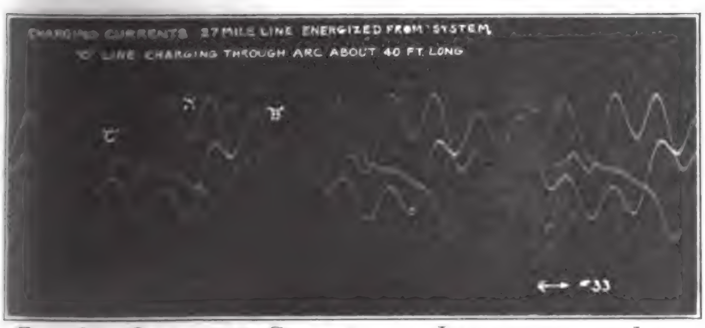


Fig. 34—Charging Current of Line through Long Open-Air Arc

The arc held on for about six seconds, in quiet air, rising continually higher until it broke. The total length measured along the arc reached a maximum of from 60 to 70 ft. with a 23-ampere arc. Such an arc increases the charging current to the line due to wave distortion as shown in Fig. 34.

In view of the extremely long arc and the liability of its being blown into adjacent conductors it was decided to abandon the idea of breaking charging current upon air-break switches but to operate the sectionalizing switch stations so that the air-break switches would be used only for separating parallel lines.

Tower Design

Comparative studies were made of the cost of single- and double-circuit towers as follows: Clearances from insulator shield to tower of four five and six feet; conductors of 605,000, 1,000,000 and 1,500,000 circular mils of aluminum with steel core and copper conductors of resistance equivalent to the two larger sizes of aluminum; flexible and rigid towers, all towers to stand the unbalanced pull of any two conductors being broken and anchor towers to stand all conductors being broken on one side.

The combinations and permutations of these variables are many.

The final decision was for single-circuit towers, as costing no more per circuit than double-circuit construction.

Steel-core aluminum was preferred above copper, and the extra cost of obtaining six ft. clearance over that for four ft. was so insignificant that the minimum of six ft. was adopted.

The only condition under which double-circuit towers would seem advisable would be where it was extremely difficult to get rights of way. It also appeared somewhat hazardous to tie up such quantities of power as 240,000 kw. upon a single-tower line, at all events with the size of the whole system such as it will be for some few years to come.

Protective Devices

The 150-kv. lightning arresters now in service at Big Creek generating plants, Vestal and Eagle Rock substations, will remain in operation, but it is not intended to install any arresters on the 220-kv. lines.

The two existing Big Creek tower lines have one ground wire on each and these will of course remain. They are of service in distributing ground current over several towers in the case of insulator arc-over. They are also felt to be of some slight mechanical advantage, although with rigid towers this would only be effective after a tower member buckled or a tower foundation washed out or gave way.

Mention has been made of the possibility of automatic sectionalizing of the line; this would be effected by balanced relays.

The method now used of breaking arc-overs is to lower the fields of generators and synchronous condensers until the arc breaks, and upon building up the field once more the generators pull into step, if they have fallen out of synchronism, and service is resumed in about one minute on an average.

Plans are under way to make this operation automatic which should result in a great saving of time.

Conclusions

Transmission at 220 kv. has been invested with a certain glamour, and the further investigation has been carried the more certain it appears that transmission at this voltage will only differ in degree from transmission at lower voltages, with which we are familiar. No new or startling effects are expected or appear probable.

The unequal voltage distribution over long insulator strings can be eliminated to the degree where individual units will be stressed less than they now are on lines in commercial operation. This is effected by shield rings which at the same time can be so designed as to keep any accidental arc well away from the insulators. Corona upon insulators and hardware is also prevented.

Standard suspension insulators can be used, so that 220-kv. transmission need not wait upon the design and trial of new types of insulator.

Transformers and switches are already developed, and have been built by more than one manufacturer.

The corona constants of large cables are known within rather narrow limits so that lines can be confidently designed to have definite known losses.

The charging current of commercial lines is also sufficiently well determined so that calculations of voltage regulation will be accurate.

There are therefore no apparent obstacles in the way of 220-kv. transmission, the only requirement being that the amount of power to be transmitted shall be sufficiently large, and the distance great enough to warrant the cost of 220-kv. equipment. The increased carrying capacity of the transmission lines then more than offsets the equipment cost and 220-kv. transmission becomes more economical than at any lower voltage.

Note on the Development of an Electron Tube Amplifier

Which Uses 60-Cycle Alternating Current to Supply Power for the Filaments and Plates

BY. P. D. LOWELL

Associate Physicist, Bureau of Standards.

Electron tube amplifiers now form an important part of practically all radio receiving sets except the most simple types. Storage cells, which have heretofore usually been required for operating amplifiers, require constant attention, are bulky and heavy, and have other serious disadvantages. The dry cells, which are often used as a source of plate voltage, have a comparatively short life and are expensive and inconvenient. It would be much more convenient to use an amplifier which could be supplied with power from 110-volt, 60-cycle mains.

This paper describes a five-stage amplifier which operates satisfactorily on 60-cycle supply for both filaments and plates. This amplifier has three radio-frequency stages and two audio-frequency stages, and uses a crystal detector. A special transformer with five windings is used, the primary being supplied with 110-volts a-c. The 60-cycle current when used in an ordinary amplifier circuit introduces a strong 60-cycle note which offers serious interference. This has been practically eliminated by balancing resistances, grid condensers and special grid leaks of comparatively low resistance, telephone transformer in the output circuit, and crystal detector instead of electron tube detector. In the final form of the amplifier, there is only a slight residual hum which is not objectionable. The amplification obtained with a-c. supply was as good as that obtained with the same amplifier used with d-c. supply. The complete unit is light, compact, and portable. For the reception of damped waves, the amplifier as constructed operated most satisfactorily for wave lengths from 200 to 750 meters. This range was determined by the working range of the radio-frequency transformers used. By using suitable radio-frequency transformers, it is expected that the amplifier will be effective for the reception of damped waves and undamped waves as long as 10,000 meters. For the reception of undamped waves, a separate heterodyne should be employed. The paper gives circuit diagrams, and states the values of the condensers, resistors and inductors used.

ELECTRON tube amplifiers now form an important part of practically all radio receiving sets, except the most simple types. Such amplifiers are in fact necessary to receive distant stations, or when using coil antennas. For good operation, amplifier tubes require for the filament a source of voltage of very constant value (usually about 6 volts) and for the plate a source of voltage of from 40 to perhaps 300 volts. The filament voltage is usually supplied by storage cells, and the plate voltage by dry cells. The maintenance of these cells in operating condition, especially the storage cells, is often a source of much difficulty and annoyance. The storage cells are necessarily bulky and heavy, require constant attention to maintain proper charge and density of electrolyte, give off injurious acid or other fumes, and are subject to considerable variations of voltage during the period of discharge. The development of an amplifier which can be supplied from the ordinary 110-volt a-c. lighting mains is of considerable practical importance, since it would eliminate the practical difficulties of maintaining storage cells. The amplifier using such a-c.

supply has the important advantages of reliability, convenience, and cheapness both in first cost and operating cost.

Such an amplifier using five stages of amplification has been developed at the Bureau of Standards. There are three stages of radio-frequency amplification and two stages of audio-frequency amplification. It is the purpose of this note to describe briefly this amplifier.

The first arrangement tried consisted of one radio-frequency stage of amplification, detector and one audio-frequency stage. The filaments of the three tubes were lighted by 6 volts supplied by a step-down transformer, the primary of which was connected to the 110-volt, 60-cycle power mains. The circuit is shown in Fig. 1.

In Fig. 1, the filament lighting transformer is shown at *A*, supplying voltage for the filaments of electron tubes *B*, *C* and *D*. The amplifier input circuit is connected to the grid of tube *B* and to the slider of the balancing resistance *E*, the latter having a resistance of 200 ohms and being connected across the filament line. A radio-frequency transformer is shown at *H*,

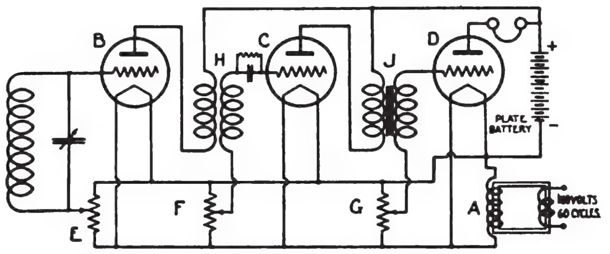


FIG. 1—TWO-STAGE AMPLIFIER CIRCUIT, USING TUBE DETECTOR

a balancing resistance at *F*, an audio-frequency transformer at *J*, and another balancing resistance at *G*. The purpose of the balancing resistances *E*, *F*, *G*, is to keep the normal voltage of the grids at a steady value with respect to the average voltage of the electrical midpoint of the filament and thus to eliminate the hum which variations of the grid voltage would cause. These balancing resistances are adjusted until the hum is eliminated. Reception was accomplished with this circuit but there was considerable 60-cycle hum present in spite of the beneficial effect of the balancing resistances.

The employment of a crystal detector in place of the electron tube detector reduced the 60-cycle hum very considerably. This circuit is shown in Fig. 2.

When an electron tube is used as the detector, there is impressed on both the plate and the filament a 60-cycle a-c. voltage which, although small, becomes very objectionable when amplified by one or two stages of audio-frequency amplification. When the crystal detector is used, no 60-cycle voltage is supplied to the detector circuit. The radio-frequency transformer whose output is delivered to the detector circuit prevents the passage in any appreciable amount of 60-cycle current supplied to the radio-frequency stage, and such voltages are not present in the crystal detector circuit and do not reach the input of the audio-frequency stage.

The employment of a crystal detector may at first seem objectionable, since with the crystal as ordinarily used it is rather difficult to find a point of good sensitivity. But tests on this amplifier showed that careful adjustment of the crystal detector was not necessary because the radio-frequency amplification preceding

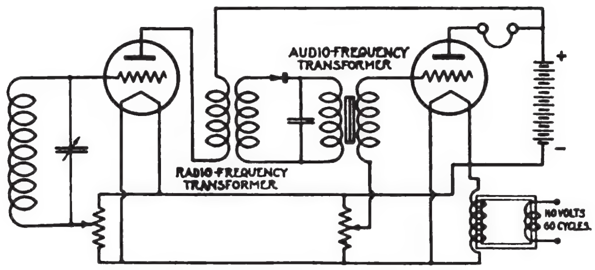


FIG. 2—TWO-STAGE AMPLIFIER USING CRYSTAL DETECTOR

the detector usually gave sufficient signal strength so that a point of sufficient sensitivity could be easily found.

This circuit gave quite good results. The 60-cycle hum was practically eliminated and the crystal detector gave almost as good rectification as the tube detector.

It was found that better amplifying action could be obtained by inserting condensers of about 0.02 microfarad capacity, shunted by 2-megohm grid leak resistances, in the grid circuits, in series with the sliders of the balancing resistances. The grid condensers and grid leak resistances allow the grids to assume a normal voltage which is more favorable for amplifying purposes. The leak resistances allow any accumulated charge on the grids to leak off to the filaments. Still better amplification and quieter operation was produced by

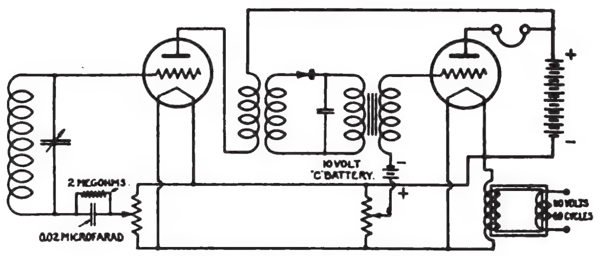


FIG. 3—TWO-STAGE AMPLIFIER USING CRYSTAL DETECTOR
With grid condenser for radio stages and grid battery for audio stages.

replacing the series grid condenser and leak in the audio stage with a 10-volt battery giving a negative charge to the grid. A battery of dry cells was used for this purpose; since only an extremely small current is required, the life of the dry cells is practically their shelf life. This gave a circuit as shown in Fig. 3.

Alternating current rectified by means of a gas-filled two-element rectifier tube (a "Tungar" tube) was tried as a source of filament power but the residual hum was much greater than when unrectified alternating current was used. This is because of the fact that during rectification, the wave form becomes distorted and it becomes impossible to stabilize the grid voltage by means of the balancing resistances.

In the above-mentioned tests, a plate battery was used for convenience, but this was replaced by alternating current which had been rectified by means of an electron tube and smoothed out with condensers of large capacity. The rectification circuit for the plate voltage supply is shown in Fig. 4.

In Fig. 4, the primary P of the transformer T is connected to the power mains, and winding R gives 8 volts for the filament of the rectifier tube W. Winding S gives 300 volts which is rectified by the tube W and smoothed out by the condenser Q, which has about 10 microfarads capacity. This gives at terminals M and N a high-voltage direct current which is quite suitable for use on the plates of the amplifier tubes. Rheostat Z varies the brilliancy of the filament of the rectifier tube and, simultaneously, the voltage for the plates.

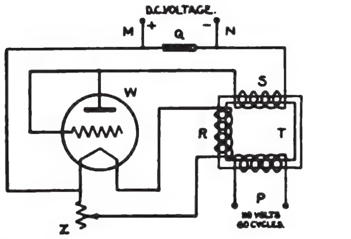


Fig. 4—Rectification Circuit for Plate Voltage Supply

The use of a loud-speaking telephone receiver such as the "Magnavox" was made possible by applying to the field coil of the loud speaker an alternating current rectified by a "Tungar" rectifier tube. The impedance of the field coil was sufficient to smooth out the pulsating current to such an extent that the hum was not annoying. It was also advantageous to couple the loud-speaking reproducer circuit to the plate circuit of the last amplifier tube by means of a one-to-one ratio telephone transformer with a 0.02-microfarad condenser in series with the telephone circuit. This helped considerably to reduce the residual hum in the telephones.

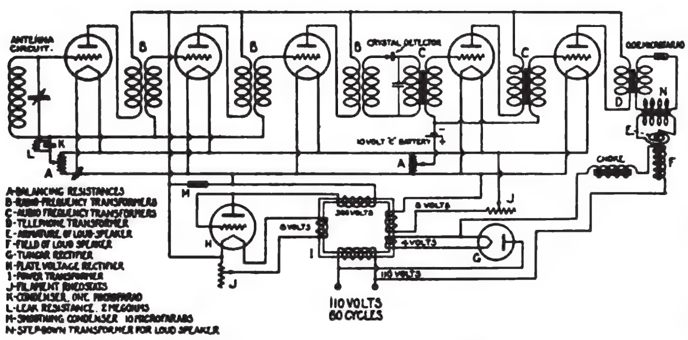


Fig. 5—Final Complete Circuit of Five-Stage Amplifier Using Crystal Detector

Using 60-cycle alternating current to supply power for the filaments and plates.

The final circuit is shown in Fig. 5, and includes three stages of radio-frequency amplification, galena crystal detector, two stages of audio-frequency amplification, loud-speaking reproducer, and the necessary power transformer and rectification circuits.

This final circuit gives good amplification, with a slight residual hum which is not great enough to be objectionable when receiving signals of ordinary readable strength. The residual hum is of course more objectionable when extremely weak signals are being received. Radiotelephone music and conversation are clearly reproduced.

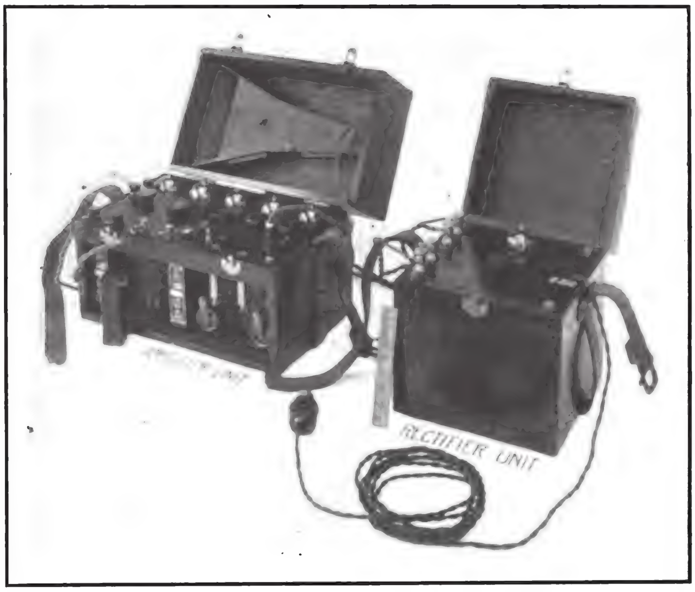


Fig. 6—Assembled Rectifier and Amplifier Units

The amplifier was operated under normal conditions using the usual sources of direct-current supply, and then switched over to alternating-current supply. This comparative test showed the a-c. supply to give as good amplification as the d-c. supply.

For the reception of damped waves, the amplifier as constructed operated most satisfactorily for frequencies from 400 kilocycles to 1500 kilocycles per second (750 to 200 meters). This frequency range was determined by the working range of the radio-frequency transformers used. By using suitable radio-frequency transformers, it is expected that the amplifier will be effective for the reception of damped waves for frequencies as low as 30 kilocycles (10,000 meters). This amplifier has also been found effective for the reception of undamped waves, when used with a separate heterodyne.

The special transformer with five windings and the rectifier tube were assembled in one box, and the amplifier tubes and amplifier transformers and other apparatus were assembled in a separate box. This was done to avoid having the amplifier immediately adjacent to the special transformer, from which it would pick up considerable 60-cycle hum. The assembled rectifier unit measured about 8 in. by 8 in. by 9 in. and weighed about 21 pounds. The assembled amplifier unit measured about 8 in. by 11 in. by 14 in. and weighed about 21 pounds.

Fig. 6 shows the rectifier unit and the amplifier unit as completed, with the plug to connect with the 60-cycle lighting current. A six-inch rule is shown leaning against the rectifier unit.

Mr. F. W. Dunmore was a coworker and participated in the development of this instrument. The author wishes to acknowledge his indebtedness to Mr. R. S. Ould for helpful suggestions in preparing this paper.

An Overpotential Test for Insulators

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Some of the factors met in the design of insulators and characteristics of routine electrical tests are discussed in this paper.

A new overpotential test is described with its application and effects. Results of this test make possible a higher standard of practise in the manufacture and use of transmission line insulators.

Ever increasing responsibility is being placed upon transmission line insulators. To establish by specific tests that each insulator put into service has a liberal initial factor of safety and further to be assured that the insulator will be proof against deterioration in service is the ideal toward which we are working.

Factors in Design

PERMANENT high dielectric strength in an insulator is the fundamental requirement, but this is not an independent factor in the determination of sound insulators. Along with dielectric strength we must consider the flash-over voltage of the insulator, its shell thickness and its impulse ratio. If these three be high the dielectric strength should be correspondingly higher.

The ratio of puncture voltage to the product of flash-over voltage times impulse ratio may be taken as the electrical factor of safety in service. This factor of safety may be increased by higher dielectric strength and by lower flash-over voltage, while the impulse ratio is rarely utilized as an independent variable in designing insulators. Higher dielectric strength in turn is a function of thickness as well as dielectric strength per unit thickness. Thickness is a matter of design while unit dielectric strength in the case of porcelain insulators, is contributed by effective solution of the ceramic problem. These two factors may appear to be independent but they are, as a matter of fact, strictly interdependent. Thicker insulators have replaced the thin sections of former days, but unless this increase in thickness is accompanied by better porcelain, the sought-for increase in dielectric strength is but temporary. The thicker the porcelain, the more necessary it is to prove its soundness.

Thicker shells of good material are better. They are stronger mechanically and more quiet electrically. But what shall tell us that they are not of a quality whose inferiority is hidden by the thickness of the shell? The electrical test is the only practical means of proving each insulator.

Routine Electrical Tests

The routine electrical test is depended upon to weed out poor material. The potential of this test as usually applied, is flash-over voltage. The potential required to puncture a piece of good quality may run twice the voltage of flash-over. Some insulators fail on flash-over test. Those that pass the test, range in dielectric strength between flash-over and the puncture strength of sound porcelain. Some insulators that pass this flash-over test have inherent weakness that would cause them to fail if the potential difference were higher or applied for a longer time. Application of voltage longer than a few minutes produces but few additional punctures so that attention has been devoted to increasing the voltage of test.

The most obvious possibility of applying higher potentials is to immerse the insulator in oil as in puncture testing. This has never become a routine test on insulators for service because of its many disadvantages. On account of the presence of this medium of low dielectric constant and high dielectric strength the application of full potential is limited to areas actually in intimate contact with the conducting terminals. This restriction localizes and intensifies the dielectric flux to such an extent that damage may be done to perfectly good insulators. Aside from this, the immersed oil test is expensive to apply.

Two other tests that have had commercial application in routine testing of suspension insulators, secure a slight excess of voltage above 60-cycle flash-over by utilizing the impulse ratio or the time lag of the insulator. They are known as the high-frequency test and the impact test.

The High-Frequency Test

This test employs damped wave trains of the order of 100,000 to 200,000 cycles a second applied for a few seconds. The vigor and time with which this test can be applied are somewhat limited by the tendency of the flash-over streamers to become localized and then to start digesting the porcelain by local heating. The detection of a small percentage of unsound material that the 60-cycle open flash-over test would have allowed to pass has heretofore justified the use of this test. It cannot be relied upon for the detection of the greater part of material that is improperly fired nor for many checks that escape visual inspection.

The Impact Test

In the electrical impact test a spark gap in series with the test causes a slight amplitude of damped high frequency to be superimposed upon the low-frequency wave.

A condenser across the line adds to the slight surge of high-frequency energy when flash-over of the auxiliary gap occurs. The intensity of this test varies with the energy available from the source and from the

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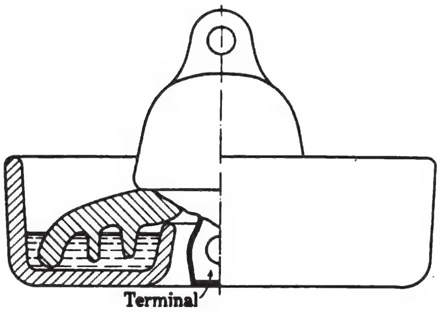
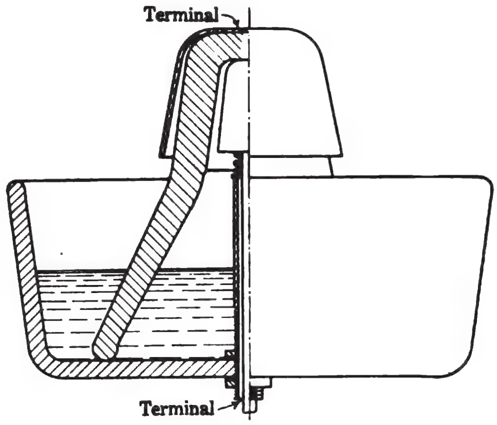
condenser and depends upon a nice proportioning of the electrostatic capacity of the auxiliary gap to the capacity of the insulator, and is further affected by the resistances in the circuit. If the capacity of the gap is too low the insulator charging current leaks across the gap too early to cause much high-frequency amplitude to remain on the crest of the 60-cycle wave. If the capacity in parallel with the auxiliary gap is too high, the insulator flash-over starts at normal frequency and the impact effect is lost again. The impact effect is greatest with an auxiliary sphere gap discharging just before the low-frequency voltage wave reaches maximum value. As the possibility of utilizing the impulse ratio of the insulator in commercial routine testing depends upon the electrical constants of the circuit, a standardized test of this nature is not readily attained and verified.

At best, either the high-frequency or the impulse test adds but a few per cent to the voltage available to test the dielectric strength of the insulator. It must be assumed that voltage surges in service will equal in intensity any test voltage depending for its added effectiveness upon the steepness of its wave and the time lag of flash-over. Such tests cannot raise the minimum factor of safety above unity, much less establish a definite margin of safety or weed out insulators that may deteriorate in service.

The Overpotential Test

To make it possible to test insulators at any definite voltage desired from flash-over to high puncture, the following overpotential test has been devised and used for commercial testing. In this test (Figs. 1 and 2) the insulator is placed in an insulating dish which holds a sufficient depth of oil to form an electrical flash-over seal at the rim of the insulator at the same time leaving the head and center part of the shell exposed to the air. The inside terminal is connected with a conductor passing up through the center of the dish. In effect the dish becomes part of the insulator which temporarily, for testing purposes, acquires an extended flash-over distance, sufficiently long to prevent flash-over at the chosen testing voltage.





Figs. 1 and 2—Arrangement for Overpotential Test

Application of the Test. With the above simple arrangement many possibilities at once appear. On account of the presence of air inside and outside, the vital center of the insulator is bathed in active corona (Fig. 3) which diffuses the potential without concentration and without local heating and injury to the insulator; although covered with this ionized air the temperature of the insulator at the end of test is not hot. The area exposed to active potential may be limited as desired by raising the oil level.

On account of absence of flash-over (see spark gap, Fig. 4), the specified test voltage can be maintained at a constant value by holding a fixed voltmeter reading showing potential impressed upon the primary of the testing transformer. This value can be verified accurately at intervals by checking against the spark gap without the disturbing surges that accompany calibration with parallel flash-over. Either the sphere gap or needle gap can thus be used to calibrate the test without the discrepancies that usually attend the determination of flash-over voltage by means of these two

Fig. 3—Overpotential Test—Center of Insulator Bathed in Active Corona

gaps. Not only will the surge from a flash-over test cause the gap to discharge and vice versa, but the sphere gap is more sensitive than the needle gap and usually more sensitive than the test to this voltage kick because of differences in impulse ratios. By eliminating flash-over we eliminate the indeterminate effects noted and make it possible to apply to the insulator an accurately

FIG. 4—OVERPOTENTIAL TEST—SPARK GAP

determined voltage of approximately sine wave. The importance of applying low frequency may be gained from an observation of the effects of the "high-frequency" test. It appears that the surface digestion of the porcelain is due to a lack of penetration of the dielectric stress deep enough to cause a uniform potential gradient throughout the thickness of the dielectric. It appears that the energy per half cycle of the damped high-frequency wave is not sufficient to supply the energy required by dielectric hysteresis and to overcome the counter electromotive force due to time lag of the dielectric in giving up charge except for the surface of the insulator which is immediately in contact with the rapidly reversing potential. The fact that continuous waves of the same order of frequency heat the dielectric many times more rapidly than this damped wave train test, indicates the degree to which the energy is curtailed. This phenomenon may be compared with the skin effects in a solid electric conductor which make the body relatively impenetrable to high-frequency electromagnetic induction.

By confining the high-frequency energy to the surface of the dielectric, destruction proceeds piecemeal through thermal expansion and spalling of the affected region, rapidly taking advantage of the initial local or superficial difference in dielectric strength and accomplishing a puncture only by a process of progressive destruction. This type of failure requiring several thousand successive cycles for its completion, does not appear to correspond to the line failures caused by surges or by lightning as these latter seldom show evidence of progressive digestion of the porcelain. Such line failures are probably completed by a few cycles of high energy which shatter the dielectric by applying a fairly uniform potential gradient to insulators of weakened dielectric strength.

Results of the Test. The fact that the punctures produced by this overpotential applied in a smooth sine wave of low frequency are of marked suddenness and violence, would indicate that this test eliminates fairly material that would be likely to puncture in service due to low dielectric strength of the total path of puncture.

In the overpotential test, involving as it does a higher intensity of applied potential, it is a matter of first importance to know that insulators which have safely passed the test have not been weakened because of the test so as to sacrifice part of their useful life. Two points of information are available in this condition. The first is the dielectric strength as actually determined by puncturing under oil insulators that have passed the overpotential test. The curve of distribution of punctures as obtained on the test itself provides the second source of information. (Fig. 5.)

From records of puncture under oil of 1 per cent of several thousand suspension insulators, representative of six months' production, minimum and average puncture values were increased about 20 per cent and 15 per cent respectively, above previous values on similar units tested by liberal flash-over with impact.

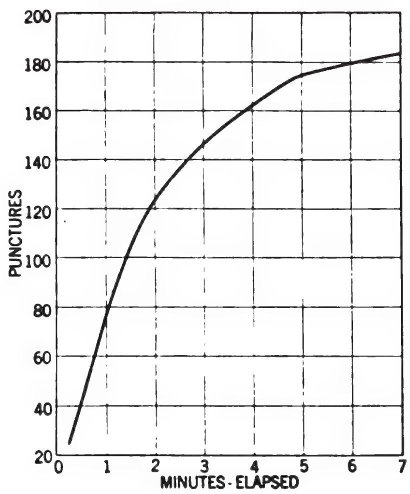


FIG. 5—TIME DISTRIBUTION OF PUNCTURES—OVERPOTENTIAL TEST

10-in. suspension insulators. Potential applied 125 per cent of flash-over. Time of test, 5 min.—2 min. after last puncture.

Maximum values of puncture were fully as high after applying the overpotential test. In no case was an oil puncture value below the overpotential used on the test.

The curve (Fig. 5) giving distribution of punctures throughout the five minutes of test shows that two-thirds of the failures occurred in the first and second minutes

of test and failures diminished in succeeding minutes, indicating that at the voltage of test no evidence of dielectric fatigue had appeared. If the time of application were to cause increasing loss this curve would show a tendency to rise again. For the purpose of securing further data on the effects of time and intensity of voltage application, a few units were left through successive tests, a total of about twelve hours, without puncture.

Specification Limits. When standard 10-in. uncemented suspension shells are given a vigorous flash-over test for several minutes as is usual, and then tested after assembly, the final 60-cycle flash-over and the "high frequency" together puncture a certain small percentage. When the overpotential test is applied instead of the above final tests, it eliminates about four times as many units and thereby removes the units that would be most likely to fail in service. This margin of dielectric strength or test voltage may be fixed at as high a value as experience proves necessary to weed out material not reliable as a dielectric. The exact value to which it may prove economical to limit the test voltage will be determined by a balance between the cost of failures in service and the cost of insulators of the grade specified. That point can be worked out and a definite standard of dielectric strength established on as sound a basis as engineers are accustomed to use in the purchase of steel for example. The point is that this overpotential test makes possible a definite specification and a means of fulfillment. With a knowledge of the kind of material that goes up on the line, we have a definite starting point for service records.

Design versus Material

It may be objected that the foregoing lays too much stress on dielectric strength and overlooks matters of design and structural details that have undoubtedly been the cause of some failures of insulators. While this problem of design is important, specific information is available for its solution. Physical failures other than dielectric may be classified as to type and definite provisions made in the insulator structure to correct the trouble. Given a porcelain insulator of tested high dielectric strength, the permanence of its electrical and mechanical characteristics is also assured by the same test. For such porcelain coefficients of elasticity and thermal expansion become stable. Design tests for mechanical strength run fairly uniform and liberal factors of mechanical safety can be employed. Few purely mechanical failures are experienced on account of external loading. Insulators of stable dielectric material, with adequate provision for differential thermal expansion and contraction, do not fail in service.

Differentials within individual shells as well as between the shells and the metal and cement composing the structure, should be considered in compensating for temperature variations.

Stresses within the insulator can be kept well within the strength of the porcelain with a good margin of resistance to meet external service loads. When porcelain is fairly treated in design with due regard to its known characteristics, it attains a high order of reliability.

Porcelain as a Material for Insulators

Some of the facts about porcelain may be recalled with interest. Within its strength it is three times as flexible as steel since its elastic coefficient is about ten million. Its yield point is also its ultimate strength. There is no permanent elongation. In this particular it compares very favorably with the metals in reliability. When the metals approach the condition for zero ductility they become very unreliable. Steel when alloyed or treated to such a degree that the elastic limit approaches the ultimate strength, becomes impossible to handle without cracking. Reliability is in proportion to ductility of the metal. Porcelain in this respect is of superior toughness because of its thorough anneal and its flexibility.

By taking advantage of its characteristics, the very limitations of porcelain may become a source of strength. A rod of porcelain is a case in point. Values of modulus of rupture in bending for moderate-size rods are observed to be twice as high as values of ultimate strength in tension. This is about the same ratio as found in cast iron and is due to analogous causes. In both cases segregation of density occurs to some degree in the forming process. Skin friction in the die from which the clay is extruded and in the mold through which the iron flows, slightly differentiates the surface from the interior material. In the subsequent shrinkage of the cast iron when it solidifies and in the shrinkage of the clay as it dries, and later as the clay is fired, and further as it is cooled, all of the changes progress from the outside to the inside, accentuating the initial differentials and leaving the rod with a shell under compressive stress and the center volume in tension in all directions. It is now readily seen that when such a rod is stressed in tension, a value lower than the true strength is obtained because part of its strength is cancelled internally. When stressed by bending, the initial compression in the side opposite the load, reverses to a tension stress only after the load has caused flexure, and at the instant of rupture the greater part of the area of cross-section is under tension while the neutral axis is shifted to the compression side. As porcelain is many times as strong in compression as it is in tension, this means favorable loading and an unduly high value of modulus of rupture is found.

The above case of the rod is discussed at some length to illustrate in a quantitative way, the cause and effect of internal stresses. This simple case may give some idea of the value of careful design and indicate why some designs must fail. The hazards accompanying increase in thickness may be appreciated to some degree

by this analogy between porcelain and cast iron. Sound cast iron is made and relied upon; sound porcelain can be made and relied upon in designs that respect its properties.

Porcelain now has this advantage, its soundness as a dielectric and to a great extent, the permanency of all its qualities can be tested by the application of a sufficiently high potential and this can be accomplished without deterioration of what strength it may possess.

Conclusion

Meeting the increasing demands for reliability in transmission of power, a test has been developed which applies to an insulator a definite chosen potential in excess of its highest normal flash-over voltage.

By the elimination of doubtful material, the minimum factor of safety of the insulators can be raised to a point where sound dielectrics are assured.

This test gives to the purchaser a definite basis for specifications and a means of attaining a higher duty insulator.

It gives the operating engineer a knowledge of what grade of insulators he puts on his line—a basis for service records that will mean something.

In this test the manufacturer will find a spur to progress and a proof of quality.

Three Thousand Tests on the Dielectric Strength of Oil

BY J. L. R. HAYDEN and W. N. EDDY
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Review of the Subject.—Three thousand successive disruptive strength tests are herewith shown. These were made in six groups with 500 tests in each group under constant conditions of test. Three groups of tests were taken of standard insulating oil with three different shapes of the electrostatic field; small sphere gap, large sphere gap, and sphere-needle gap. One group of tests was made with commercial and another with chemically pure benzol. The last group was made with air as a dielectric. A brief review of results and conclusions follows.

In measuring the voltage by a single sphere gap, set in air with reasonable care, the maximum error of test does not exceed 4 per cent and the average error is 1 per cent. In the average of six successive tests the maximum error decreases from 4 per cent to 2.9 per cent and the average error decreases from 1 per cent to 0.6 of 1 per cent.

In contrast to air, the behavior of oil is very erratic. Successive observations of its disruptive voltage, made under most carefully controlled conditions, differed by a percentage many times greater than the accuracy of the test,—the minimum value was as low as 49 per cent of the maximum. This inconstancy of the disruptive strength of oil appears inherent to the material. Little of the variation is dependent on the shape and size of the electrostatic field. Much of the variation is due probably to the complex chemical and physical nature of the oil.

Benzol gives far more consistent values of disruptive strength than oil, the more so the purer it is, but nevertheless benzol is much more erratic than air.

Under successive tests oil, first slowly and then more rapidly, deteriorates by carbonization due to the disruption. Benzol deteriorates very rapidly at first, and then becomes fairly constant. Filtration restores the initial disruptive strength, but the filtered material seems to deteriorate more rapidly than new material. This information indicates that there is either an intermediate chemical state of the disintegrated product or an absorption.

THE difficulty of obtaining consistent data on the behavior of insulating oil under disruptive dielectric stress is well known. It has been found that, because of this erratic behavior of oil, most available data on liquid insulation are so incomplete as to be of limited value.

To study this phenomenon of the erratic behavior of oil and its possible cause and explanation, 1500 successive breakdown tests were made on oil, 500 on one sample each (I) with a short sphere gap, which were described in a recent paper by the same authors,[1] (II) with a long sphere gap and larger spheres at higher voltage, (III) with a point-sphere gap, to see what effect the size or shape of the electrostatic field had.

Then 1000 successive tests were made with benzol, (IV) 500 with commercial benzol and (V) 500 with chemically pure benzol, to see whether the erratic behavior was specific to oil or shared by other liquid insulators.

Finally 500 successive tests were made in air at atmospheric pressure, to determine the possible accuracy of disruptive tests.

As Peek, Ryan and Whitehead have shown that the dielectric strength of air is uniform within errors of observation, comparison of this set of tests with the other five should show how much of their non-uniformity is due to the methods of testing, errors of observation etc.

Each sample was tested successively 500 times at the same gap length by gradually applying voltage to the electrodes (submerged in the sample) until the gap between them was broken down. All possible precautions were taken to prevent the presence of foreign particles, dust, etc. in the samples of liquid insulation, and to insure that each test was made in exactly the same manner. The rate of applying the voltage, which is all important in testing insulation, was made exactly the same for each test by using a motor operated rheostat. All 3000 breakdowns were taken in exactly the same manner as the first 500. Further details as to preparation of the sample, method

Presented at the Annual Convention of the A. I. E. E., Niagara Falls, Ont, June 26-30, 1922.

1. *Five Hundred Tests on the Dielectric Breakdown of Oil,* Hayden and Eddy, JOURNAL, A. I. E. E., February, 1922.

The points on the zigzag curve show the low-tension voltage (transformer ratio 580:1) at each of 500 successive breakdown tests made under constant conditions. Each of the ten points on the dotted line is the mean of the adjacent 50 breakdowns (25 on each side). Each of the ten points on the lower solid line shows the average variation of the adjacent 50 breakdowns (25 on each side) from their mean.

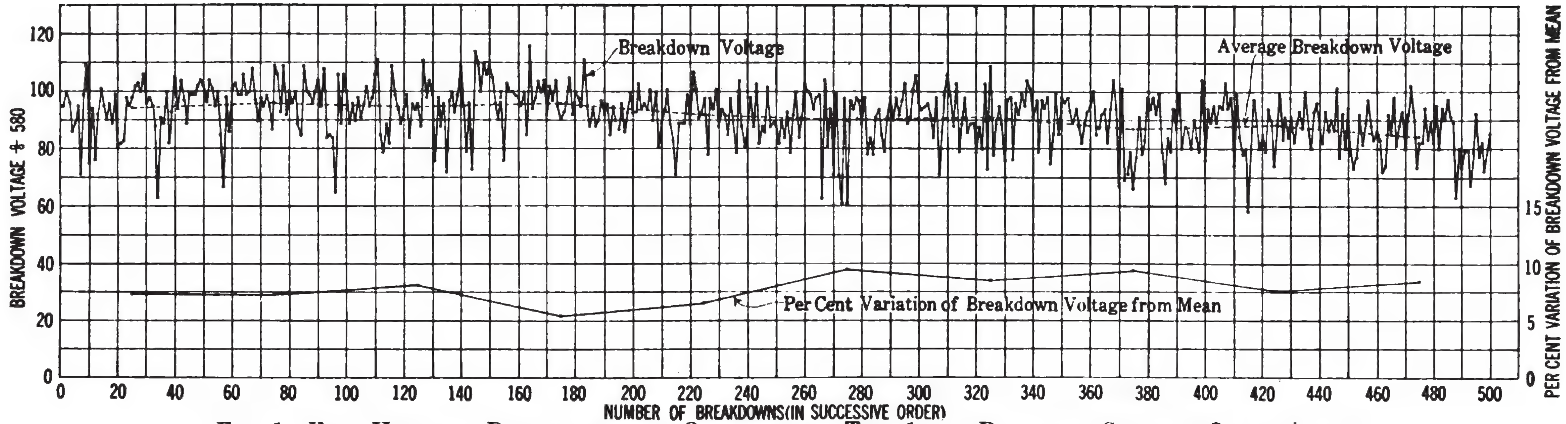

Fig. 1—Five Hundred Breakdowns on Oil between Two 1-cm. Diameter Spheres 2 mm. Apart

The points on the zigzag curve show the low-tension voltage (voltmeter coil ratio 2000:1) at each of 500 successive breakdown tests made under constant conditions.

Each of the ten points on the dotted line is the mean of the adjacent 50 breakdowns (25 on each side).

Each of the ten points on the lower solid line shows the average variation of the adjacent 50 breakdowns (25 on each side) from their mean.

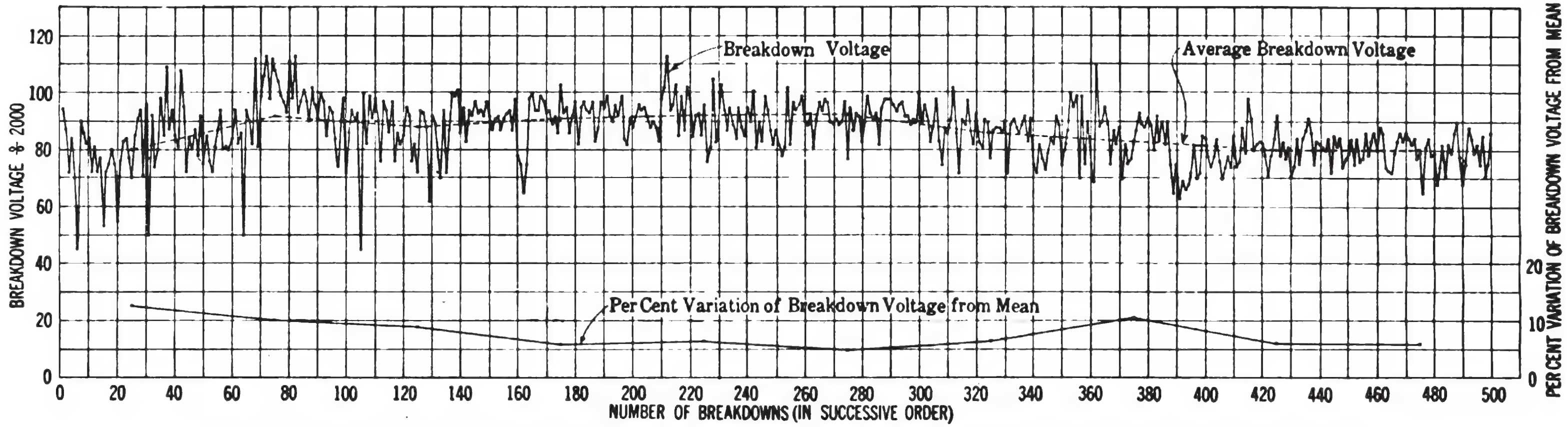

Fig. 2—Five Hundred Breakdowns on Oil between Two 2.54-cm. Diameter Spheres 27 mm. Apart

The points on the zigzag curve show the low-tension voltage (transformer ratio 120:1) at each of 500 successive breakdown tests made under constant conditions.

Each of the ten points on the dotted line is the mean of the adjacent 50 breakdowns (25 on each side).

Each of the ten points on the lower solid line shows the average variation of the adjacent 50 breakdowns (25 on each side) from their mean.

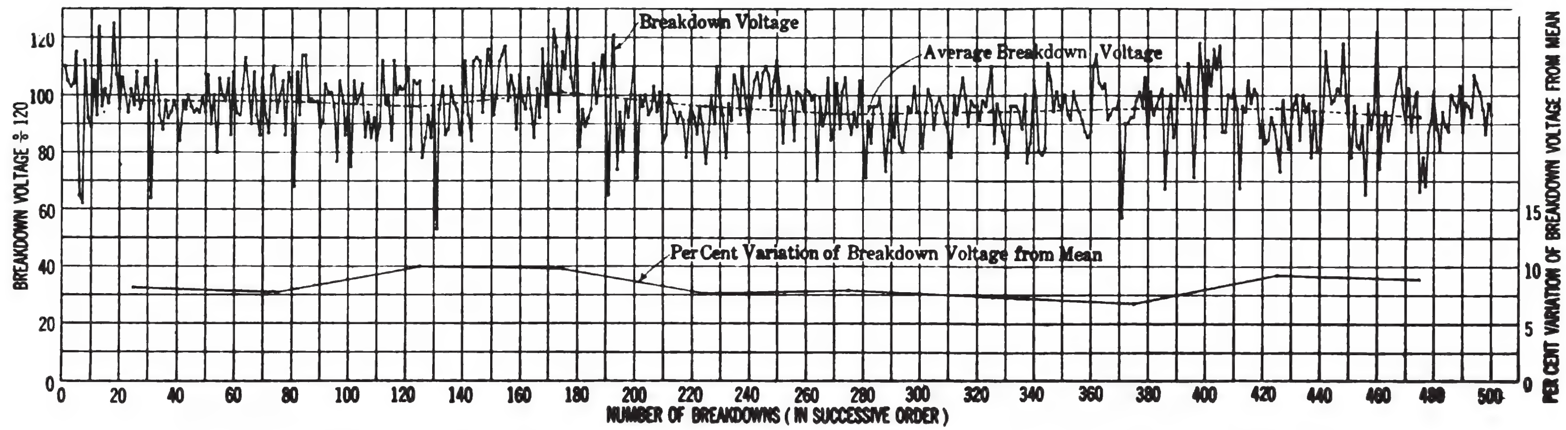

Fig. 3—Five Hundred Breakdowns on Oil between 2.5-cm. Diameter Sphere and Needle 2 mm. Apart

The points on the zigzag curve show the low-tension voltage (transformer ratio 340:1) at each of 500 successive breakdown tests made under constant conditions.

Each of the ten points on the dotted line is the mean of the adjacent 50 breakdowns (25 on each side).

Each of the ten points on the lower solid line shows the average variation of the adjacent 50 breakdowns (25 on each side) from their mean.

After 300 breakdowns the benzol was removed from the container, refiltered, returned to the container and the tests continued.

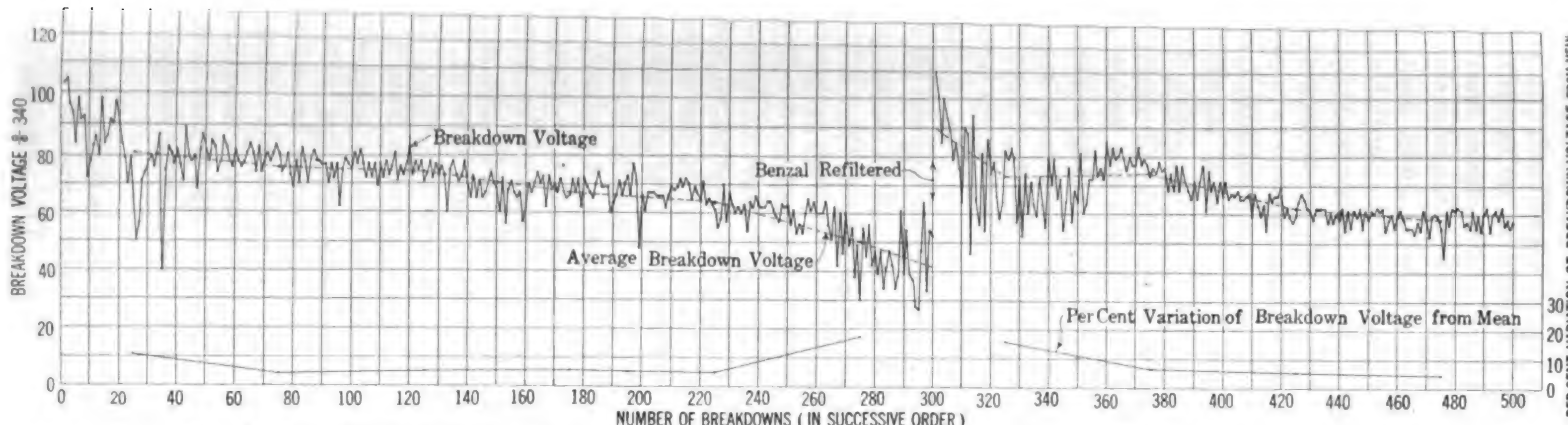

Fig. 4—Five Hundred Breakdowns on Commercial Benzol Between Two 1-cm. Diameter Spheres 2 mm. Apart

The points on the zigzag curve show the low-tension voltage (transformer ratio 340:1) at each of 500 successive breakdown tests made under constant conditions.

Of the 14 points on the dotted curve, each of the first 5 (at the left) is the mean of the adjacent 10 breakdowns (5 on each side). Each of the remaining 9 points is the mean of the adjacent 50 breakdowns (25 on each side).

The 14 points on the lower solid curve are distributed similarly. Each of the first 5 is the average variation of the adjacent breakdowns (5 on each side) and each of the remaining 9 is the average variation of the adjacent 50 (25 on each side) from their mean.

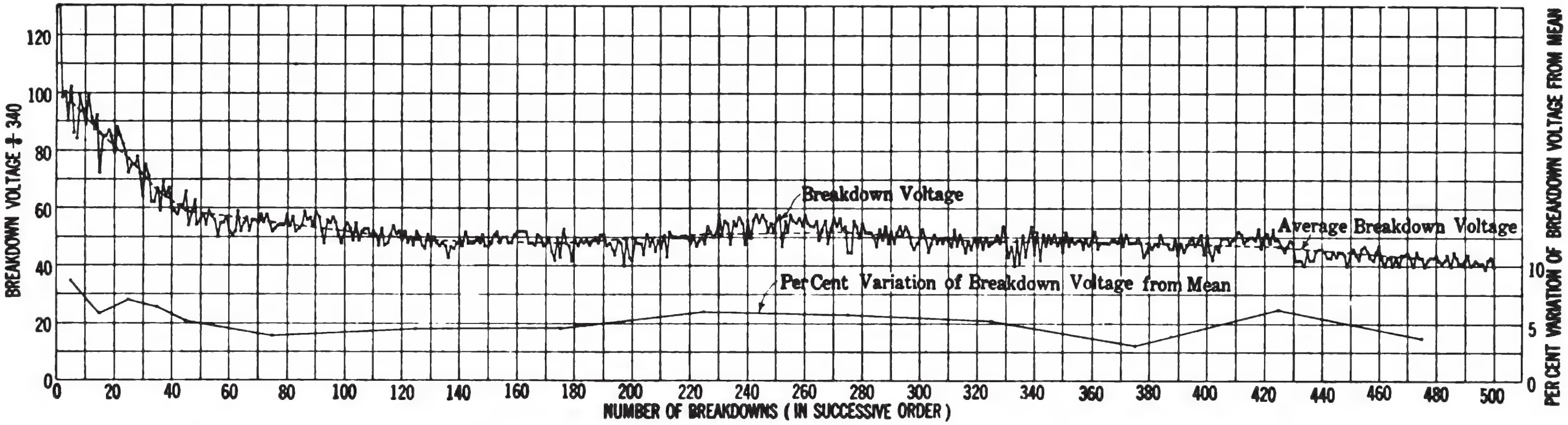

Fig. 5—Five Hundred Breakdowns on Pure Benzol Between Two 1-cm. Diameter Spheres 27 mm. Apart

The points on the zigzag curve show the low-tension voltage (transformer ratio 300:1) at each of 500 successive breakdown tests made under constant conditions.

Each of the ten points on the lower solid curve is the average variation of the adjacent 50-breakdown voltages (25 on each side) from their mean.

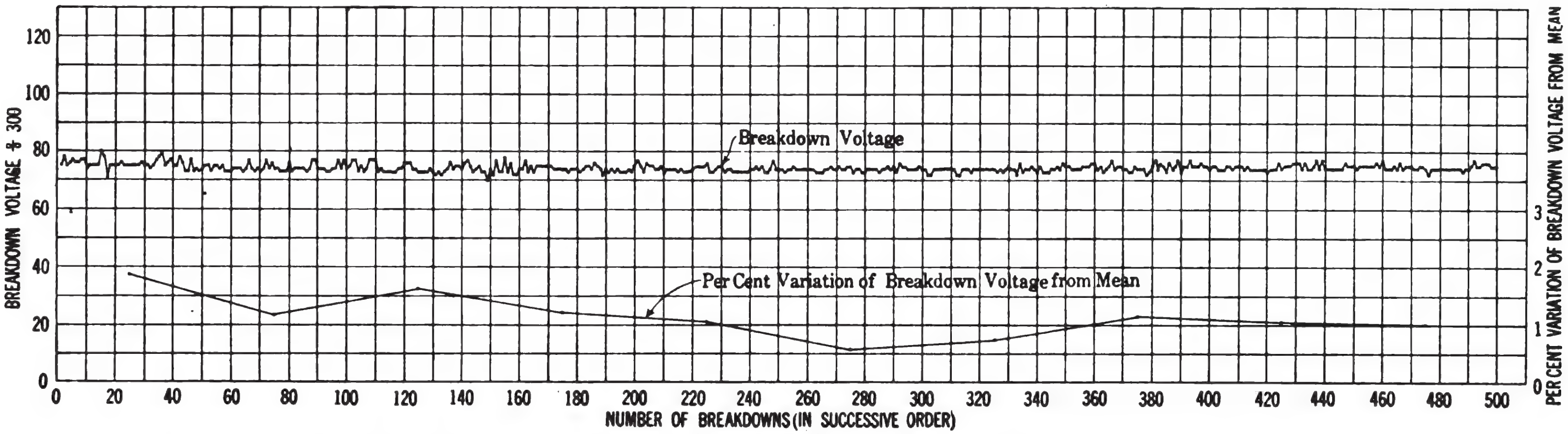

Fig. 6—Five Hundred Breakdowns on Air Between Two 2.54-cm. Diameter Spheres 1mm. Apart

of testing, development of curves, etc. will be found in the former paper. (loc cit.)

The data taken on each sample is shown graphically in two ways: (1) (*a*) The actual breakdown voltage in succession, (*b*) the average breakdown voltage, and (*c*) the per cent variation from the mean are plotted as ordinates against the number of the breakdowns as abscissas. (2) The per cent of the total number of breakdowns is plotted as ordinate against the per cent variation from the mean as abscissa. Each graph of this second group is a probability curve and was calculated from the data by the $\Sigma\ \Delta$ method[2]. The condition of the six groups of tests follow:

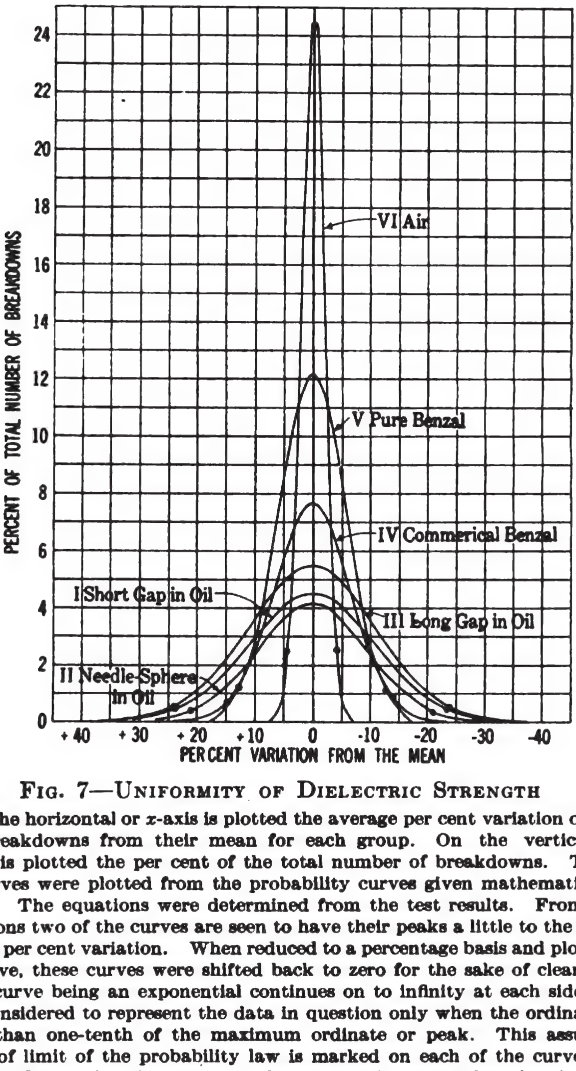

FIG. 7—UNIFORMITY OF DIELECTRIC STRENGTH

On the horizontal or x-axis is plotted the average per cent variation of the 500 breakdowns from their mean for each group. On the vertical or y axis is plotted the per cent of the total number of breakdowns. These six curves were plotted from the probability curves given mathematically below. The equations were determined from the test results. From the equations two of the curves are seen to have their peaks a little to the right of zero per cent variation. When reduced to a percentage basis and plotting as above, these curves were shifted back to zero for the sake of clearness. Each curve being an exponential continues on to infinity at each side but it is considered to represent the data in question only when the ordinate is more than one-tenth of the maximum ordinate or peak. This assumed range of limit of the probability law is marked on each of the curves by circles. Comparing the curves at these points it is seen that the air tests show variations from the mean no greater than 4 per cent, while the oil tests for instance show as much as 24 per cent variation. The equations follow:

Graph I —$y = 22.4\ \epsilon^{-.0051\ (x-3)^2}$
" II —$y = 20.7\ \epsilon^{-0.006\ x^2}$
" III —$y = 27.2\ \epsilon^{-0.0055\ (x-4)^2}$
" IV —$y = 45.8\ \epsilon^{-0.0251\ x^2}$
" V —$y = 60.8\ \epsilon^{-0.0536\ x^2}$
" VI —$y = 123\ \epsilon^{-0.232\ x^2}$

I. Five hundred breakdowns in oil between two one-cm. diameter spheres two mm. apart.

II. Five hundred breakdowns in oil between two 2.54-cm. diameter spheres 27 mm. apart.

III. Five hundred breakdowns in oil between a needle and 2.54-cm. diameter spheres 2 mm. apart.

IV. Five hundred breakdowns in commercial benzol between two one-cm. diameter spheres 2 mm. apart.

V. Five hundred breakdowns in pure benzol between two one-cm. diameter spheres 2-mm. apart.

VI. Five hundred breakdowns in air between two 2.54-cm. diameter spheres one cm. apart.

Figs. 1 to 3 show that the disruptive strength of oil is not constant and uniform, but varies in successive tests under identically the same conditions, over a wide range and in an entirely erratic manner. Comparison with Fig. 6, the air curve, shows that the variations between successive tests in oil are many times greater than the possible accuracy of breakdown tests in air, and that the cause of the variation therefore must be inherent to the material, the oil.

Comparison of the three oil curves in Figs. 1, 2, 3 and 7 shows that there is little difference between them. In other words, the erratic behavior of oil is not the result of the particular shape or size of the electrostatic field. The per cent variation between successive tests is a little less in a large sphere gap, and a little greater in a sphere and needle gap, than in a small sphere gap, but the difference is small compared with the difference between oil and air gap. In our former paper the point was made that with spheres in oil the actual breakdowns at the higher voltage fell below the breakdowns to be expected by the law of probability, possibly due to the approach to a true dielectric strength of the oil. The large sphere gap showed the same characteristics, while the sphere and needle gap gave a curve which was symmetrical on both sides of the mean, that is, apparently did not show this effect.

Examination of the two benzol curves, in Figs. 4, 5 and 7, shows that the variation between successive breakdown tests in benzol are materially less than in oil, especially so with chemically pure benzol, but nevertheless are still much greater than with air. Benzol therefore is intermediate in the uniformity of disruptive tests, between air and oil. Possibly this is due to the more uniform chemical constitution of benzol compared with oil.

Comparison of the two benzol curves shows that the uniformity of breakdown is greatly increased by the increased purity of the material. This suggests that the erratic behavior of oil may be due to the complexity of its chemical and physical structure.

The benzol curves were found to follow the law of probability both above and below the mean breakdown without showing any of the unsymmetry given by spheres in oil. With the same amount of energy back of the discharge the benzol seemed to carbonize much more rapidly than transil oil. Before testing, the benzol was, of course, transparent and colorless. After only 20 breakdowns it was opaque and black. Fig. 5

2. Engineering Mathematics. C. P. Steinmetz.

shows that during the first 50 breakdowns the dielectric strength decreased very greatly due to carbonization, and fell to less than half the initial value. After this however, additional carbonization of the benzol caused only gradual deterioration, no more than that of oil and the dielectric strength of the benzol containing colloidal carbon had become approximately constant. Fig. 4 shows that after refiltering, the benzol seemed to deteriorate slightly faster than at the beginning of the test.

The 500 breakdowns in air are seen to be much more consistent than even the benzol tests. As air itself is considered to have a definite and uniform dielectric strength these tests prove that the erratic behavior of the oil and even of the benzol greatly exceeds that which might be caused by the methods of testing, errors of observation, etc. That is, the comparative non-uniformity of the oil and benzol must be due to some inherent characteristics of the materials themselves.

On the probability curves of Fig. 7, the points where the probability has dropped to one-tenth its maximum value, have been marked by circles. While of course each probability curve as exponential extends to infinity most of the observed breakdown values are contained within the range of voltage between the maximum probability and the one-tenth value, and the width of the probability curve between the two circles of one tenth value thus offers the means of characterizing and comparing the different curves, with regards to their scattering of the breakdown values. Thus we get the following table, showing the range of the voltages over which the breakdown tests are scattered, in per cent of the mean value:

TABLE I

Percentage range of breakdown voltage, from mean:

Air	± 4 per cent
Chemically pure benzol	± 12 per cent
Commercial benzol	± 14 per cent
Oil	± 24 per cent

Table II shows a tabulation of the average per cent error that might be expected for (1) a single test, (2) three tests, or (3) six tests on oil if the mean of 500 successive breakdowns is taken as the correct dielectric strength and any variation from that as the error. It is seen that sphere-gap tests in air give an accuracy sufficient for their use for voltage determinations, especially when using the average of several observations, but that to get consistent results in the commercial testing of oil a gap should be so designed as to inherently average as many breakdowns as possible.

TABLE II

	Air	Long sphere gap in oil	Short sphere gap in oil	Needle sphere gap in oil
Single Breakdown Test		per cent	per cent	per cent
Average error	1.1	7.8	7.8	8.4
Maximum error	6.7	48.5	34.1	44.8
Maximum error except 3 readings	4.0	33.0	31.8	35.0
Three Breakdown Tests				
Average error	0.8	5.2	4.9	4.9
Maximum error	4.0	22.4	19.7	19.1
Six Breakdown Tests				
Average error	0.6	2.7	3.5	4.1
Maximum error	2.9	17.5	15.0	14.3

VALUE OF HIGHER INTENSITIES OF ILLUMINATIONS

During the past year M. Luckiesh of the Nela Research Laboratories has been investigating the effects of higher intensities of illumination on the speed of reading, and has found a definite increase of "speed of vision" as the illumination intensities increased. For ordinary reading matter (black print on white paper) the speed of reading increased 15 per cent when the illumination increased from 4 to 16 foot-candles. For black print on gray paper, the increase in speed was 50 per cent when the illumination intensity increased from 4 to 16 foot-candles. These data show the value of increasing the intensity of illumination and the results can safely be extended to cover many other visual processes in factory, office or home.

Another interesting phase of the investigations was a determination of the illumination intensities voluntarily chosen by a large number of observers. For reading printed matter, such as the *Saturday Evening Post*, the mean value chosen was about 10 foot-candles (when a maximum of 30 foot-candles was available) and when the paper was dyed gray so that the print was seen on a gray background, the mean value chosen was about 17 foot-candles, the other conditions being the same.

Incidentally, it was found that the observers chose more light when the maximum available intensity was larger than when it was small. This is best shown as follows:

	Approximate Foot-Candles		
Maximum Available Intensity	10	30	45
Intensity chosen for ordinary reading	5	12	16
Intensity chosen for reading from gray paper		17	

Reading tests were used because reading is the most extensive visual activity and by using the gray background as well as the white, data were obtained which may be safely interpreted in terms of many other visual activities.

Power Development on the Colorado River

And its Relation to Irrigation and Flood Control

BY O. C. MERRILL

Executive Secretary, Federal Power Commission

Review of the Subject.—*The Colorado River drains an area of 250,000 square miles in the States of Wyoming, Colorado, Utah, Nevada and New Mexico, Arizona and California, and in the Mexican States of Sonora and Lower California. It is the third largest river basin in the United States and is fourth in volume of waters. The basin contains some five million acres of irrigable land and possibilities for power development exceeding six million horse power.*

The upper section of the river to the Utah-Arizona State line comprises 40 per cent of the basin, contains one-half of the irrigable land, supplies 87 per cent of the annual run-off, and could develop some two million horse power. Developments in this section, particularly storage, are likely to result in conflict between power and irrigation. The middle section from the Utah-Arizona line to the mouth of the Williams River comprises 35 per cent of the area, contains comparatively little irrigable land and supplies only 7 per cent of the annual run-off. This section, mainly in deep canyon, has a drop of about 3,000 feet and could produce four million horse power. The lower section with 25 per cent of the area of the basin has two and a quarter million acres of the best irrigable lands, provides 6 per cent of the run-off and has comparatively small power resources.

The most valuable lands in the basin are in the Imperial Valley, which, due to the fact that it is below sea-level and that the delta of the Colorado is very unstable, is constantly menaced by floods. The chief immediate problem on the river is, therefore, flood protection for this valley. Such protection can be secured by a storage reservoir either at the head or at the foot of the middle section. The latter site appears the more immediately available. The upper site would, however, afford adequate flood protection and give irrigation regulation for many years, and would, in addition, control the middle section for power development. The location of the primary storage on the river is an important matter and may determine the whole course of power development.

The rate of power development on the Colorado is a question of markets. With the exception of the mining district of Arizona, which might absorb 100,000 horse power, there is no present market in the basin sufficient to justify large-scale development. The most available outside market is Southern California which apparently could furnish sufficient demand for the initiation of power development on a considerable scale. Extension of such development in the future would involve interconnection, common control, and long-distance transmission.

Applications involving the Colorado and aggregating four and one-half million horse power are on file with the Federal Power Commission which has suspended action awaiting decisions upon collateral matters. The individual states have control over the appropriation of waters within their limits. To avoid the danger of future interstate litigation over water rights, the Colorado River Commission was created under authority of Act of Congress to work out a "compact" or "treaty" between the several States. It has not yet reached any conclusions. The stream also is international and irrigation rights in Mexico are involved. Finally, there is conflict over the question whether development shall be made by private capital or by the Government. These various conflicts of interests and of agencies are likely to postpone for a considerable time the solution of the problem of Colorado River development.

CONTENTS

Introduction

ONE of the most important and interesting of our present day engineering problems is the control and development of the Colorado River. Its interest and importance arise from the fact that it involves the irrigation of millions of acres of land, the production of millions of water horse power, and the protection from floods of millions of dollars of property values, and that it affects the general economic interests of seven of our States and two of the states of Mexico. It is of interest also in its political relations —using this term in its etymological, not its ordinary sense. Seven sovereign states claim in the use of the waters of the Colorado rights which in the aggregate may exceed its possibilities. Its waters can not be put to use without the sanction of the states in which the use is proposed and without the concurrent sanction of the Federal Government which owns the lands necessary for such use and which possesses a general control over the river from the fact that it is an international stream. It remains to be seen to what extent political considerations will modify engineering considerations in the solution of the problem.

The two main branches of the Colorado rise, the one in southwestern Wyoming, the other, in central Colorado. The length of the river from the headwaters of the Green to the Gulf of California is about 1750 miles. Its basin with an area of about 250,000 square miles includes practically all of Arizona, nearly one-half of Colorado and of Utah, one-fifth of Wyoming and of New Mexico, one-tenth of Nevada, and a narrow strip in California along the California-Arizona boundary. The Imperial Valley in California, though not topographically a part of the Colorado basin, should also be included because of its dependence upon the waters of the river and because of its intimate relation to the general problem of river control. Of the area of the basin some five million acres, or about one acre in 30, appear economically irrigable. Claims, however, have been made that there is a much larger amount of available irrigable land. The annual run-off of the

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river at Yuma averages about 18 million acre-feet. The average discharge is about 24,000 cubic feet per second, with variations from a minimum of 4000 second-feet to a maximum of 150,000 second-feet on the main river, and to 240,000 second-feet by inclusion of the Gila. The steep slope of the river and its large volume make it capable of producing some six million water horse power, or two-thirds as much as is developed in the United States today.

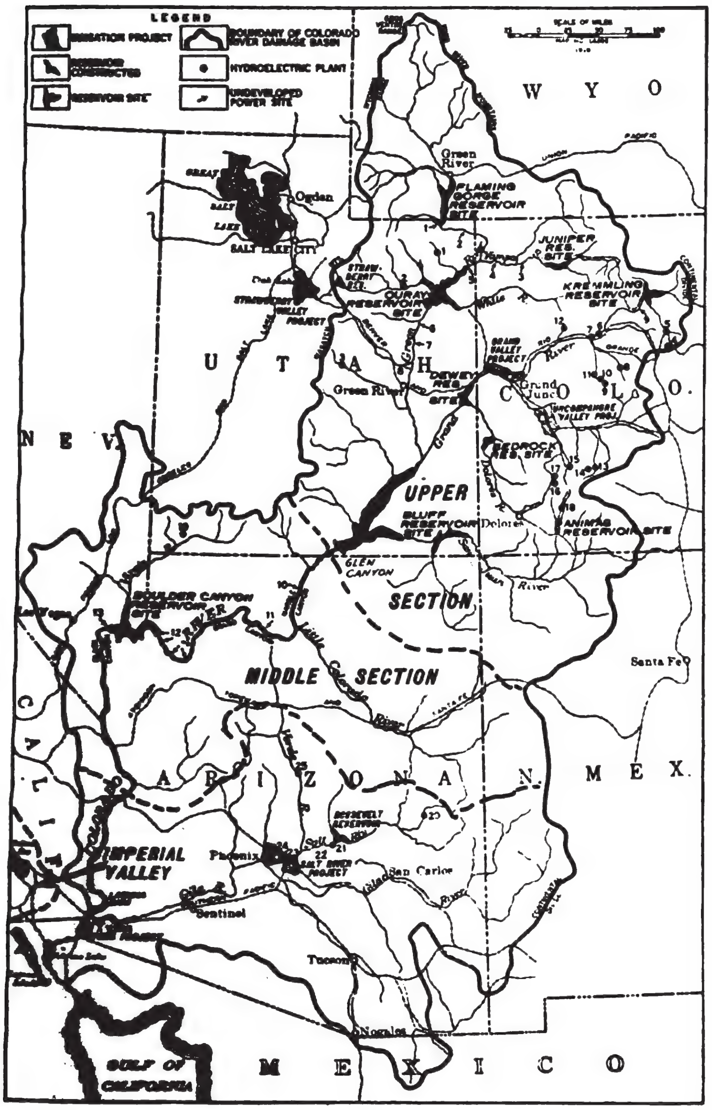

Fig. 1—Colorado River Basin
Divided into sections.

Three Main Sections of River

A discussion of the general problems of the Colorado will be made clearer if we divide the river into three sections and consider the characteristics of these sections and their relations to each other. (See Fig. 1).

The upper section from the headwaters to the Utah-Arizona line, just below the mouth of the San Juan, comprises about 40 per cent of the area of the basin and affords about 87 per cent of the total run-off, or an average of about 15,000,000 acre-feet per annum. In this section are some 2,500,000 acres of irrigable land, one-half of the estimated total in the basin. It also has power possibilities aggregating 2,000,000 horse power. In this section, both upon the main stream and upon its tributaries, are many favorable reservoir sites by means of which it would be practicable to regulate the flow of streams for irrigation within the section, or for power development both within the section and outside, or, if desirable, for flood control on the lower river. In so far as the tributaries are involved, these several uses would conflict to a considerable degree and only a careful study of the whole section could determine the best combination of uses. At the lower end of the section is the so-called Glen Canyon reservoir site which has an important bearing on all developments and uses of water below.

The middle section from the mouth of the San Juan to the mouth of the Williams comprises about 35 per cent of the area of the basin and supplies about 7 per cent of the annual run-off. There are no irrigable lands along the river in this section and only some 250,000 acres on the tributaries, none of which can be reached from the main river. In this section, however, there is a total drop of about 3000 feet, capable, if fully utilizing the average annual run-off entering the section, of producing 4,000,000 horse power. Except for the Boulder Canyon site near the lower end of the section, which would have no effect on the greater part of this section, there appear to be no storage sites capable of providing any considerable amount of seasonal storage. Dams erected for power development would be primarily for the purpose of concentrating head and of providing pondage for daily load regulation. Seasonal regulation would be dependent upon storage in the upper section.

The lower section from the mouth of the Williams River to the Gulf and including the drainage of the Gila and the Imperial and Coachella valleys in California, comprises some 25 per cent of the total area of the basin and furnishes about 6 per cent of the average annual run-off. Its power possibilities are relatively unimportant, but it contains some 2,250,000 acres of irrigable land, the most fertile and most valuable in the basin, of which a large part is periodically endangered by floods. There appear to be no reservoir sites of consequence below Boulder Canyon on the main river, but there are such sites on the Gila which could be used both for irrigation and for controlling the Gila floods.

Viewed solely from the physical standpoint, the upper section of the basin might have its primary development directed either toward irrigation or toward water power; or it might, as it probably will, have a combination of these two uses. On the other hand, the middle section, with the exception of storage below the mouth of the Virgin and of relatively small irrigable areas on the tributaries, is suitable only for power development. Equally clearly, the waters reaching the lower section should be devoted primarily if not exclusively

to irrigation, and the storage sites should be employed for irrigation or flood control or both.

Flood Control Problem

The most immediately pressing problem on the Colorado River is flood control for the protection of the Imperial Valley in California. I shall not attempt, however, to discuss it in detail, but merely to present certain aspects of that problem in the relation they bear to water power and to a general plan of river development.

The Gulf of California originally extended northwesterly into what is now the State of California. The silt-laden water of the river gradually formed a delta cone extending across the Gulf, cutting off the northern end and deflecting the flow of the river to the south. The waters inclosed in the northern end evaporated leaving the depression known as Imperial Valley and the Salton Sea with its surface 250 feet below sea level. The silt-formed delta is unstable. The river is constantly depositing more sediment and shifting its channel back and forth over the flat ridge—some 30 feet above sea level—which forms the crest of the delta, and there is danger at each flood season that it may break northward into the Imperial Valley instead of continuing southward into the Gulf. The river did break through in 1905 and for more than a year and a half discharged into Salton Sea before it was turned back with great difficulty and expense into its old channel. The levees which were later built to protect the valley have several times been awash in periods of floods. It is necessary to raise them about a foot a year to keep pace with the rise of the river channel, and it is only a matter of time until the river will break through again unless steps are taken to control the floods. The situation is further complicated by the fact that the works for protecting the Imperial Valley are situated in Mexico. It is this condition of affairs which has placed primary emphasis on flood control in all plans for the development of the Colorado River.

Flood conditions on the lower Colorado may be caused either by high water on the main river or high water on the Gila. Flood conditions on the main river occur annually in the summer season, due to the melting of snows on the headwaters of the streams, and continue on the average from two to three months. The maximum flood from the main river in the years of record, 1902 to 1914, inclusive, has been 150,000 second-feet. The average mean monthly discharge during the three high months of May, June and July, for this same period of record has been: May, 42,600; June, 73,100; and July, 43,500 second-feet. While the floods from the Gila approach in magnitude those of the main river, they occur in the winter season, are caused by local rains, and are of short duration. Should it happen, however, by any combination of circumstances that extreme flood conditions on the Gila should coincide with similar conditions on the main river, a break through into the Imperial Valley would be almost inevitable.

On account of the volume of water involved it is apparent that protection from Colorado River floods can be had only by storage and by storage of large capacity. It is also apparent that full immunity from flood damages can be had only by storage on the Gila as well as storage on the Colorado. Since, however, storage on the Gila has only an indirect relation to the general problem of the Colorado River, it will be given no further consideration here.

There appear to be three practicable locations for flood control reservoirs of the capacity necessary. These are on the headwater tributaries, on the main river at Glen Canyon, and on the main river at Boulder Canyon. Storage on the headwaters would require

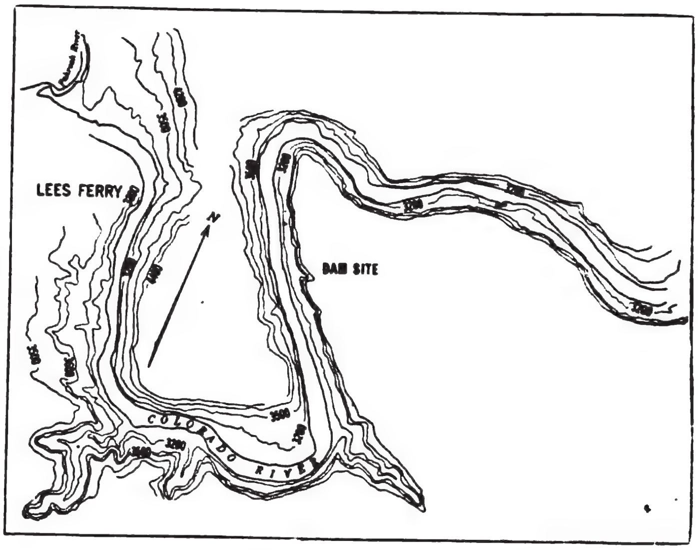

Fig. 2—Glen Canyon Dam Site
Site of proposed power development at Lees Ferry, Arizona.

several reservoirs and even though practicable from a purely flood-control standpoint, such a plan involves at least two serious objections. The operation of such reservoirs to meet the needs of the lower river would be likely to interfere to a considerable degree with the use of the waters for irrigation in the upper section and to a less degree for power development, depending upon their location and their manner of operation. If duplication of investment is to be avoided flood control reservoirs must also provide irrigation storage for the lower river. To operate for this purpose reservoirs located hundreds of miles above the lands to be irrigated would be an extremely difficult problem and would inevitably result in wastage of water and consequently in a storage capacity greater than would otherwise be necessary.

Adequate storage for both flood control and irrigation could apparently be had at the Glen Canyon site at the Utah-Arizona line. (Fig. 2.) From an irrigation standpoint this site presents similar objections,

though less in degree, to sites on the headwaters since the reservoirs would still be a considerable distance from the lands to be irrigated. From a flood-control standpoint, however, it appears adequate. It would intercept 87 per cent of the run-off of the basin, and would include every tributary of consequence above the Gila, except the Little Colorado. This stream is subject only to flash floods and enters the main river so far above the Imperial Valley that its floods can not be considered as dangerous. Storage at this point is of sufficient capacity to provide for power development and irrigation as well as for flood control, and hence would not interfere with, but would be a distinct aid to power development in the middle section.

engineering problems of magnitude. To provide the proposed minimum storage capacity of 21,000,000 acre-feet at Boulder Canyon and an equal amount at Glen Canyon will require dams of unprecedented height. Preliminary plans propose a masonry dam at Boulder Canyon some 530 feet in height above the river channel. When it is realized that the river channel has a depth of 135 feet below water level, that the river flows through a narrow canyon, and that floods in excess of 100,000 second-feet are likely to be encountered during construction, the magnitude of the engineering problems to be met will be appreciated.

Detailed investigation, particularly borings, have not yet been made of the Glen Canyon site, and the

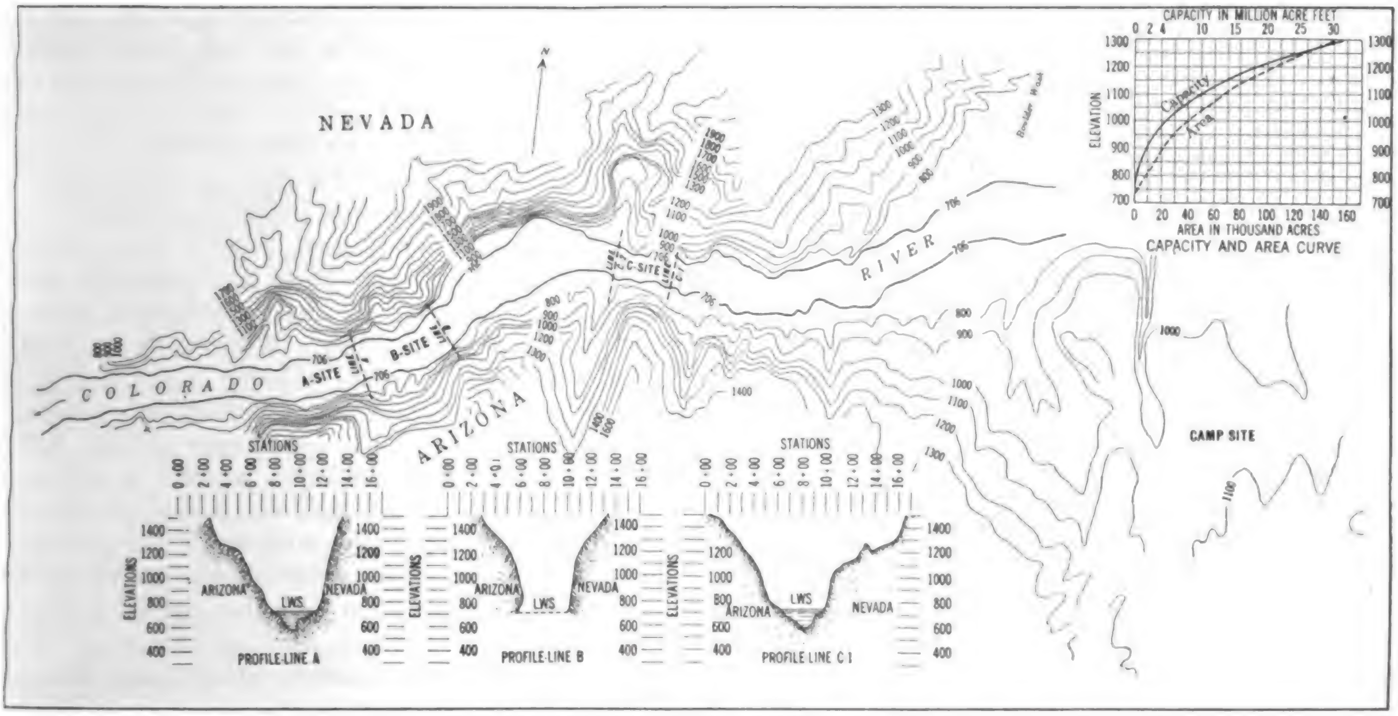

Fig. 3—Boulder Canyon Dam Sites
Topography and Profiles.

The proposed Boulder Canyon site (Fig. 3) has certain distinct advantages over all other sites if considered wholly from the standpoint of the flood control and irrigation requirements of the Imperial Valley. It is comparatively near to the irrigable lands, and operation difficulties would be reduced to a minimum. It will intercept all floods on the river, except those from the Gila. It would even be possible to ameliorate flood conditions from the Gila by stopping all discharge from the main river while the Gila is in flood. If nothing but the flood control and irrigation requirements of the Imperial Valley were to be considered, there would appear to be no doubt of the superior advantages of the Boulder Canyon site. When, however, consideration is given to the problem of development of the river as whole, the situation is by no means so clear.

Both the Glen Canyon and the Boulder Canyon sites are likely eventually to be built, and both present type of dam has therefore not been determined. If foundation conditions are not more unfavorable, this site should from the construction standpoint have certain distinct advantages over the Boulder Canyon site. The river forms a double loop at the dam site, one-half of which is 28,000 feet around but at its narrowest parts only 3600 feet across at water level, and only 2000 feet at 500 feet above water level. This condition provides better opportunity for handling water during construction than at Boulder Canyon and also affords better opportunity for constructing outlet works and spillway independent of the dam by carrying the one through and the other over the narrow section which separates the two sides of the loop.

Irrigation Problem

When we consider the relation of irrigation to power development we find that only about one acre in thirty

in the Colorado basin is irrigable, but that it has power resources more than sufficient to meet its needs for generations. Since it is likely to require all the agricultural products that its lands can supply long before it has put to use all its potential water powers, it would appear the part of wisdom to dedicate the waters of its streams to irrigation to the extent they can be efficiently used for such purpose, leaving water-power development to take the second place. If reasonably conservative practises are followed and all unnecessary waste avoided, there appears to be ample water in the Colorado and its tributaries to irrigate all lands within economic reach of the streams. The problem of water supply for such purposes is, therefore, one of equitable distribution; and this is the problem which the Colorado River Commission has been created to solve. I shall not discuss it further than to say that, if irrigation be assumed as the dominant use, there would still be opportunity to develop hundreds of thousands of horse power in the upper basin under properly developed plans and that, from the water which would be released from the upper section for the irrigation requirements of the lower section, there would still be available millions of horse power in the middle section.

Since there will be no irrigation development in the middle section of the river other than the probability of the provision of irrigation storage at the lower end of the section, and since no water will be withdrawn from the river in this section for such purpose, there will be no conflict between irrigation and power. In the upper section, however, such conflict is certain to exist. Not only will water be permanently withdrawn from the river, but storage reservoirs can not be fully used for both purposes. For this reason, as well as on account of the greater volume of water and the greater fall, the middle section is the most favorable for power development. But power development on the Colorado, as well as irrigation and flood control, requires seasonal storage. This is necessary not only to produce a regulated flow, but also, in the canyon section at least, to provide a protection against floods, for the narrowness of the river channel and the consequent restricted spillway length is likely to produce depths of discharge in flood season that might seriously restrict the height of dams that it would be save to construct.

On account of topographic conditions sufficient capacity for seasonal regulation can not be secured in the middle section except at Boulder Canyon, and that of course is available only for use at that site or below. For the greater part of the section storage must be either at the head of the section or in the upper river. If it proves feasible of construction, Glen Canyon reservoir is peculiarly well adapted for the purpose. It is situated at the crest of the steep canyon slope and appears to have a capacity sufficient to equate the flow of the river over a series of years.

The fact that this reservoir must eventually be built in connection with power developments below and that when built it is likely of itself to solve the flood problem of the main river has naturally raised the question, why build both Glen Canyon and Boulder Canyon, or if both, why build the latter first. The construction of Glen Canyon reservoir by eliminating flood conditions would make the construction of all dams in the river below far easier, cheaper, and safer. Nothing which may be done at Boulder Canyon will obviate in any degree the eventual necessity for Glen Canyon reservoir or reduce the difficulties of other construction in the canyon above. On the other hand, if Glen Canyon is built, the greater part of Boulder Canyon storage—as storage—would become useless. It would seem, therefore, that the prior construction of this dam could be justified only on one or both of two grounds. Either that the imminence of the peril to the Imperial Valley justifies the cost of the Boulder Canyon dam even if only temporarily required for flood control purposes; or that the cost is justified, independently of storage, by the additional power that could thus be produced by a dam of the height proposed. In any event, some storage below the Virgin is desirable, if not necessary, even if Glen Canyon reservoir is constructed, in order to regulate the water at that point to meet immediate irrigation requirements farther down the river. Which reservoir should be built first and whether the full capacity of both is needed are questions about which there is considerable difference of opinion. I shall only say that there appears to be enough doubt to warrant a thorough study of the upper site before commitment is made to Boulder Canyon, and that in such study due consideration should be given to power developments in the middle section as well as to irrigation and flood control on the lower section. I have placed emphasis upon this question of the location of primary storage, whether at the head or at the foot of the middle section, because it is a factor of great importance in the problems of power development and may determine the entire course of such development upon the river.

Power Development Possibilities

The extent of the interest in the power possibilities of the Colorado River (see Figs. 4 and 5) may be judged from the fact that there are on file with the Federal Power Commission 20 applications affecting the Colorado River and its tributaries aggregating four and one-half million primary horse power and six million horse power of estimated installation. It is, however, quite apparent that no such amount of power will be developed in the near future simply because it could not be disposed of. The rate of power development on the Colorado is a question of markets. The sites at the headwaters will gradually be developed to supplement the existing Utah and Colorado power systems. When we turn to the middle or canyon section, however, we find that local demands for power in this part of the Colorado basin are hardly sufficient

to justify at the present time any large-scale development. The mining market of central Arizona probably would justify an initial development of some 100,000 horse power, but to justify large-scale development

FIG. 4—COLORADO RIVER BASIN SHOWING POSSIBLE DEVELOPMENTS

Location of projects on file with the Federal Power Commission:

1. Flaming Gorge Dam Site, Utah Power & Light Co., No. 165
2. Swallow Canyon Dam Site, " " " " " " 279
3. Juniper Mt. Dam Site, " " " " " " "
4. Mabell Dam Site, " " " " " " "
5. Lily Park Dam Site, " " " " " " "
6. Blue Canyon Dam Site, " " " " " " "
7. Echo Park Dam Site, " " " " " " "
8. Island Park Dam Site, " " " " " " "
9. Split Mt. Dam Site, " " " " " " "
10. Minnie Maud Dam Site, " " " " " " "
11. Rock Cr. Dam Site, " " " " " " "
12. Rattle Snake Dam Site, " " " " " " 158
13. Kremmling Reservoir Site, Barker, W. J. " 263
14. Stillwater Canyon Dam Site, Green River Power Co., " 202
15. Glen Canyon Dam Site, Southern Cal. Edison Co., " 111
16. Marble Canyon Dam Site, Southern Cal. Edison Co., " "
17. Diamond Cr. Dam Site, Girand, J. B., " 121
18. Grand Wash Dam Site, Southern Cal. Edison Co., " 111
19. Upper Boulder Canyon Dam Site, Los Angeles, City of, " 238
20. Old Callville Dam Site, Southern Cal. Edison Co., " 258
21. Black Canyon Dam Site, Reclamation Site
22. Bulls Head Rock Dam Site, Southern Cal. Edison Co., " 258
23. Parker Dam Site, Beckman & Linden Engineering Corp., " 30

utilizing any such storage as proposed at either Boulder Canyon or Glen Canyon would require that primary markets be sought outside the basin, a situation involving long-distance high-tension transmission.

The only section which at present seems capable of furnishing the requisite demand, and the section which gives greatest promise of increasing its demand in the near future, is the southern half of the State of California. Notwithstanding the great power resources of that state, objection is already being raised against the diversion southward of the electric energy generated from the waters of the central and northern sections of the state. With the continued depletion of its oil reserves and with increasing industrial and agricultural development, the time appears not far distant when California, should it maintain its present growth of power demand, would be required to go outside its boundaries for new sources of power, even if economic considerations did not lead it to do so at a much earlier date.

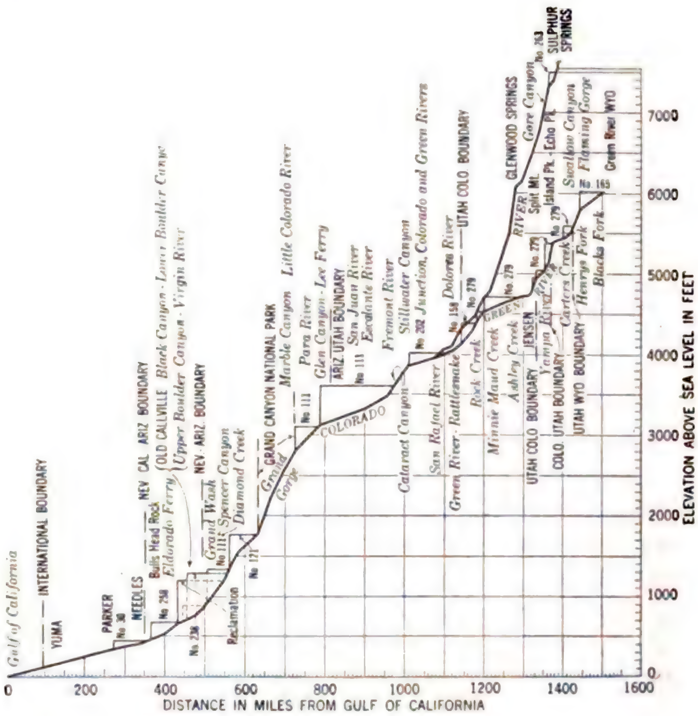

FIG. 5—PROFILE OF COLORADO AND GREEN RIVERS

Showing location of projects on file with the Federal Power Commission.
Nos. 158, 165 and 279, Utah Power and Light Company
No. 202, Green River Power Company
No. 263, W. J. Barker
Nos. 111 and 258, Southern California Edison Company
No. 121, J. B. Girand
No. 238, City of Los Angeles
No. 30, Beckman & Linden Engineering Corporation

The development of power in the basin of the Colorado for use outside will, however, be an advantage, not a disadvantage, to the people and the industries within the basin. The potential power available is more than the basin itself is ever likely to require. If power is developed on such a scale and at such a cost that it can be economically delivered in large quantities, hundreds of miles from the point of generation, it can be economically delivered near at hand in smaller quantities, and this fact, if the power is developed under proper auspices, would result in the extension

of facilities to existing local markets and in the development of new ones; for the most complete disposition of its products is the ultimate object of power development. The mining areas within the basin, the railroads which traverse it, the towns within it and along its margin, all would be sought out as users of power once development were made and the main transmission system established. Distribution of power throughout a sparsely settled area is, however, likely to be attempted only through extensions from a transmission network constructed primarily to serve other and more extensive markets elsewhere. The states within the Colorado basin would never have secured the railroad service they now possess had they not been on the main routes between the Mississippi Valley and the Pacific Coast. They will be in a similarly favorable position with respect to electric power service when trunk transmission lines are constructed across their territories.

The final factor which determines whether power sites can be utilized, the degree to which they may be developed, and the distance to which the power may be transmitted, is of course, the unit cost of energy delivered. To a considerable degree unit costs are less as quantities increase. Particularly on a stream like the Colorado where, irrespective of the size of the project, large preliminary expenses will be involved and long and expensive transmission lines will be required, large-scale development is likely to prove much cheaper in construction costs per unit of available output than small-scale development. The extent, therefore, to which the water powers of the Colorado are to be developed and the degree to which they will be made to serve the interests of the Colorado basin itself are likely to depend largely, if not primarily, upon whether the power is developed in isolated independent units or in a system of interconnected plants with a transmission network extending over the entire territory. If development proceeds by independent units, a few restricted areas will get the benefit of such part of the resources as are developed. If the other plan is followed the entire basin and all the adjacent territory may share in the benefits. Such a plan, however, can be carried out only by agencies whose authority is not circumscribed by state lines—agencies in whose own interest it will be to extend as widely as possible the territory which they serve. Such a plan does not necessarily imply either a single ownership, or Government ownership; but it does imply such an interrelationship, at least, as will insure the operation in one interconnected system of the power developments on the Colorado River.

Political and Economic Considerations

We come now to a brief consideration of what we have called the political relations of the problem. Under the provisions of The Federal Water Power Act, applicants for license must present evidence of having secured from the state, necessary rights for the diversion and use of water. It is the general rule of law within the Colorado basin that he who first puts the waters of a stream to use has a first right in their use. On this doctrine of priority of appropriation, extensive rights to the use of the waters of the Colorado have been acquired on the lower river, for it is that section of the river which is being the most rapidly developed. The fear has consequently arisen in the states in the upper section that, before the time when they can put what they believe is their share of the water to use, rights to such share will have been acquired on the lower river, particularly if power developments utilizing the full flow of the stream should be authorized on the middle or lower river. Because of this fear and in the hope that the matter might be settled without the endless interstate litigation that would otherwise be almost inevitable, a proposal was made that the several states affected enter into a treaty or compact by which they should mutually agree on the apportionment among themselves of the waters of the river. Under the provisions of the Constitution, such a compact or agreement between states requires the assent of Congress. This assent was given by Act of Congress of August 19, 1921, which authorized the creation of a commission to be composed of one representative from each of the seven interested states, who, together with a member appointed by the President, should form a Compact Commission, and should report their conclusions to Congress on or before January 1, 1923.

This Commission has been appointed with Secretary Hoover as the representative of the United States and chairman, has held several sessions, but has thus far come to no agreement. Under the terms of the Act creating the Commission, its authority is limited to the determination of an "equitable division and apportionment" of the waters of the river among the states. It has no authority to grant rights itself, and its powers do not conflict with those of the Federal Power Commission or other federal or state agencies. Since, however, its conclusions might affect or be affected by the approval of applications by the Federal Power Commission, action upon such applications has been suspended awaiting the conclusions of the Colorado River Commission.

There are also international relations involved. The Colorado River forms the boundary between the southwestern tip of Arizona and the Mexican State of Lower California. Below the Arizona line it separates Lower California from Sonora. Some 190,000 acres of land in Mexico are now being irrigated from the river, and it is estimated that 630,000 additional acres are irrigable, a total of 320,000 acres or 40 per cent of the irrigable area tributary to the river below Boulder Canyon. Under such circumstances it is manifest that international comity, if for no other reason, requires that this situation be taken fully into consideration in any plans of Colorado River develop-

ment. In its Preliminary Report on the Problems of Imperial Valley and Vicinity of January, 1921, the Reclamation Service recommended equitable participation by the Mexican Government in the cost of storage works, and arrangements with that Government for the construction and maintenance of flood protection works on Mexican soil. Such participation and arrangements could, of course, be brought about only by the concurrent action of the two Governments.

There is also the question of the degree to which the United States should itself take part in power or other developments along the river. It is argued, and with apparent justification, that the cost of flood and irrigation storage is greater than the irrigation interests alone can bear and that, therefore, the Government should itself construct the works and recoup itself by sale of power, some 600,000 horse power of which could be developed at Boulder Canyon. Whether this arrangement would or would not effect an equitable distribution of benefits among irrigators and power consumers, I am not prepared to say.

There are furthermore those who advocate development at Government expense of all the powers along the Colorado River, the distribution of such power by the Government at cost, and the prohibition of any development by private capital on the river. This is, of course merely an instance of the age-long contest, between advocates of public and of private ownership and operation. On account, however, of the probability that it may be found necessary that the Government participate in the development of the river at least to the extent of furnishing flood protection, general action is unlikely to be taken upon the applications before the Federal Power Commission until conclusions have been reached upon the extent, if any, to which the Government should thus participate.

Finally agreement among the several interested agencies should be reached on the general procedure and the general plan of development to be followed on the river, in order that whatever work is done or projects constructed may fit into a scheme for the fullest practicable utilization of the river for all uses to which its waters are adapted. There is an apparent existing need for additional power in certain sections within the basin. The several interested agencies should, therefore, reach their conclusions at the earliest practicable date so that the present order of suspension may be lifted.

Summary

The primary elements of a general plan for river development appear to be as follows: (1) Storage at the headwaters for irrigation in the upper section and for such power development in this section as can be accomplished without undue interference with irrigation; (2) storage below the San Juan of sufficient capacity to control floods and to regulate the water available at that point for power use in the middle section; and (3) storage below the Virgin sufficient, at, least, for regulation to meet irrigation requirements of the lower river and for such additional flood protection as may be necessary or desirable. If this or some similar plans can be agreed upon, and an equitable apportionment of the waters effected, the details of the immediate application of the waters of the river to their respective uses in the individual sections will be greatly simplified, and work may be started on the series of developments upon which the economic progress of the whole Southwest primarily depends.

HYDROELECTRIC PROJECT FOR KINGS RIVER, CAL.

The San Joaquin Light & Power Corporation has been granted a license for the term of 50 years for a hydroelectric power development on the North and West Forks of Kings River, in California, which will involve an estimated expenditure of $51,000,000 and have an ultimate installed capacity of 226,000 horse power. If the present rate of growth in power consumption in the vicinity of the project continues, it will be necessary to make the total capacity available by 1930.

The project will occupy about 14,000 acres of land in the Sierra and Sequoia National Forest. The developed power will be fed into the company's present transmission system through its substation at Sanger by means of a 110,000-volt transmission line to be built in two parallels, one of which will carry a single three-phase circuit on wood poles, and the other, two three-phase circuits on steel towers.

The project will consist of three storage reservoirs, formed by concrete dams respectively 190, 250 and 315 feet in height, designed to provide a combined storage capacity of 204,000 acre-feet; eight diversion dams ranging from 15 to 80 feet in height; and nine conduits of which 34 miles will be tunnel and 1 mile open ditch. It will include seven power houses, of which two will be built into storage dams and will operate under variable heads, the maxima being 175 and 245 feet, respectively. Three others will operate under heads of 365, 1420 and 1430 feet, respectively. Two power houses will operate under heads of 2350 and 2380 feet, and will be among the very few plants in the United States operating under heads exceeding 2000 feet.

Stream-gaging operations in connection with this project will be under the supervision of the Water Resources Branch of the U. S. Geological Survey. Several gaging stations have been installed by the San Joaquin Light and Power Corporation on the streams from which water is to be diverted, and a number of gages additional are to be installed in the near future.

Queenston-Chippewa Development of the Hydro-Electric Power Commission of Ontario

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Chief Engineer, Hydro-Electric Power Commission of Ontario

Review of the Subject.—*This paper covers a general description of the entire Queenston-Chippewa development of the Hydro-Electric Power Commission of Ontario, on the Canadian side of the Niagara River, which will have an ultimate capacity approximating 650,000 h. p.*

The general scheme of the development comprises an intake structure in the Niagara River at Chippewa; the utilization, by deepening and widening, of the Welland River as a part of the waterway for 4½ miles; the construction of a canal 8½ miles long from the Welland River to the forebay and screen house on the top of the Niagara escarpment about a mile south of Queenston village; and the construction and equipment of the power house in the gorge immediately below the forebay.

The entire design was carried out with the express object of producing power most efficiently from the available water at the lowest possible cost.

Important features of the waterway are described, covering the special design of intake works to avoid ice troubles; the control gate in the canal; the concrete lined canal channel, and the consideration given the design of canal, forebay, screen house, penstocks and draft tubes to obtain the best hydraulic results.

Of special interest to hydroelectric engineers is the use of the largest capacity turbines and vertical shaft generators that have ever been constructed; the size of the step-up transformers; the design and arrangement of relay systems and of switching equipment to take care of the extremely heavy short-circuit conditions; and features of the design of the power house whereby in every 50-foot length of building all equipment for one 45,000-kv-a. unit, covering penstock, turbine, generator, switching equipment, transformers and outgoing line, is accommodated; the provision of the main floor in the generator room at the top of the generator frame; also the use of a control pedestal on main floor at each unit whereby the turbine and generator may be conveniently operated.

Power for the plant service equipment is obtained from two separate small units, entirely independent of the main units, and 25-cycle current is used exclusively for service equipment motors, including the 300-ton crane equipment and the elevators.

CONTENTS

It is the intent of this paper to give an outline only of the engineering features involved in the undertaking. Under the term "Development" is included only the plant involved in supplying power to the 12-kv. busses, but as the transformer station is combined with the generating station the paper will deal with both features.

Throughout the period of preliminary study of the development and later as the design progressed, continuous use was made of models of the various structures in order that the mathematical analysis might be reinforced by actual demonstrations under the assumed conditions. Such models were made for the studies of the intake, the bends in the canal, the transitions, the diffuser at the mouth of the forebay, and on the draft tubes and station substructure. A calculation table for determining short-circuit conditions was also developed. It is believed that the beneficial result of such studies and of the care taken in the design of what are often considered minor elements of a power development will be demonstrated when complete test results are available.

Such tests as have already been made indicate conclusively that at least as high an over-all efficiency from head water to tailwater has been secured, as has ever before been obtained.

True conservation in the use of the waters of the Niagara River for power purposes demands that practically the whole fall of approximately 327 feet between Lake Erie and Lake Ontario be utilized. The various power plants now operating at Niagara Falls vary in

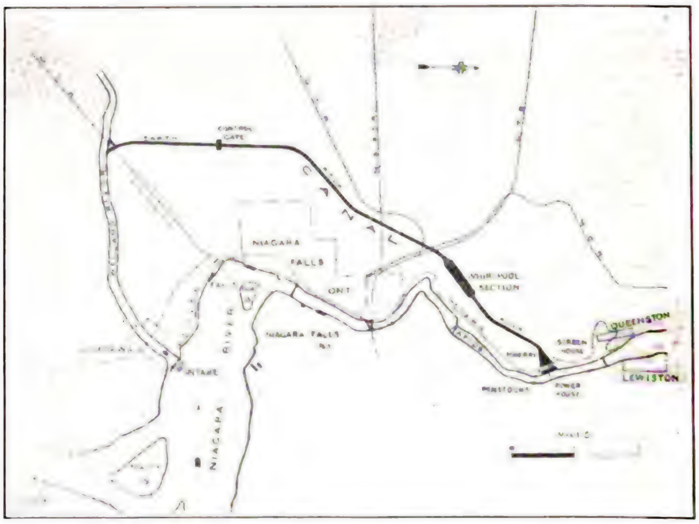


FIG. 1—MAP OF THE DEVELOPMENT

head from 130 feet to 210 feet, and with widely different degrees of efficiency.

The Queenston-Chippewa power development, the first unit of which was operated first in December 1921,

Presented at the Annual Convention of the A. I. E. E. Niagara Falls, Ont., June 26-30, 1922.

will have a normal operating head of 305 feet when the installation is complete. The conservation of head effected by the reduction of hydraulic losses to a minimum, and by refinements in the design of the various essential elements of the project as a whole, has resulted in the production of a power development which is believed to represent the best in modern engineering practise.

The plant in operation and in course of construction will consist of five 45,000 kv-a., 187.5 rev. per min. units, generating power at 12 kv., three-phase, 25 cycles, which in turn is transformed to 110 kv. for transmission. Ultimately the plant will consist of nine or ten units, with an ultimate capacity of 575,000-650,000 horse power. The subsequent units in all probability will have greater capacity than those being installed at present. Two of the units are now in service developing 110,000 horse power, which is being delivered to the existing 110-kv. system at Niagara Falls for transmission to Toronto, London and Windsor (opposite Detroit), Sarnia and intermediate municipalities.

A glance at the accompanying map, Fig. 1, will indicate the relation of the various works comprising the development. Water is taken from the Niagara River about one mile above the Falls, is conveyed through the improved section of the Welland River, a distance of 4½ miles, thence by a canal 8½ miles long, to the forebay and screen house located on the Niagara River about one mile south of the village of Queenston. From the screen house, steel penstocks encased in concrete carry the water down the cliff to the power house, from which it passes to the Niagara River.

Construction work was carried on almost exclusively by an electrically driven plant, the electrical load at times being in the neighborhood of 20,000 horse power.

Intake

On the Niagara River one of the great obstacles to securing continuity of service is the annual formal tion and flow of ice. Great fields of ice, formed in Lake Erie with its shallow bays and shores, are discharged down the Niagara River every spring, and at frequent intervals during the winter, under the proper coincident wind and temperature conditions. The river itself develops considerable anchor and frazi-ice at times of low temperature, but it never freezes over.

The site of the intake of the Queenston-Chippewa power development, at the mouth of the Welland River is favorable in that floating ice in the Niagara River does not ordinarily follow the shore lines at this point; but the smooth gradient of the river surface and the comparatively shallow water with its low velocity is unfavorable.

The removal of water in large quantities from a river heavily charged with ice is always a difficult problem, but is much simplified when a natural break in the river surface, accompanied by a sudden drop, gives a source of power for the separation of floating ice, and for its continuous disposal. The use of a horizontal diaphragm to skim the surface water with its burden of ice from the lower strata, thus permitting the upper layer to be accelerated and removed clear of the intake without objectionable eddies, while the lower layer clear of all ice is changed in direction and flows through the intake into its new channel, gives a positive and satisfactory solution.

When the natural conditions do not permit such an arrangement, as in the present case, radically different measures must be taken. To confirm certain ideas developed as a result of many years' experience and observation of the Commission's engineers, on the present plants operating on the Niagara River, an extended series of tests and experiments on large-size models were made, these models duplicating to scale the topographical conditions existing at the site of the intake. The result of these experiments contributed to the preparation of a design which, it is

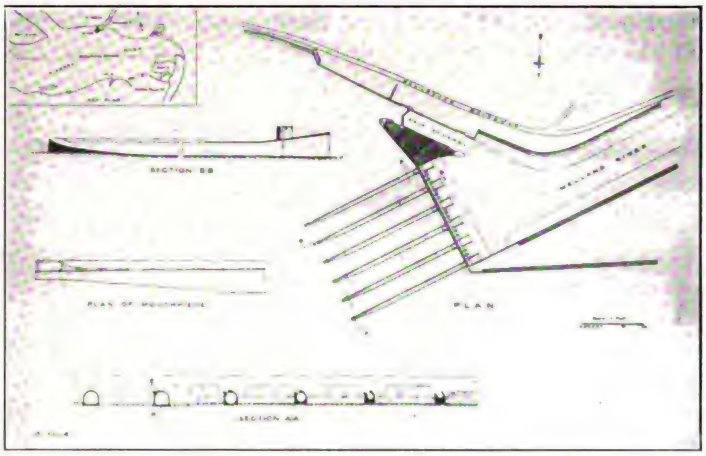


Fig. 2—Intake

confidently expected, will operate in such a way as to keep the plant wholly free of this ice menace.

The illustration of the intake, Fig. 2, shows clearly the physical nature of the design. The complete intake structure is approximately 1100 feet in length and is made up of an entrance with lock gates for navigation, a bulkhead section, and the intake proper, the latter combining two forms of intake; the conventional or surface intake consisting of a concrete barrier or boom with fifteen openings each 18 feet in width, normally having eight feet of submergence, which submergence can be increased however by means of drop gates, to any amount up to the full depth of water or 35 feet; and the submerged intake consisting of gathering tubes or draft distributors, six in number and 675 feet in length. Water enters the tubes along a distance of 500 feet through a slot on their upstream sides. These tubes are controlled by gates similar to those on the surface intake, and comprise an outer tapering section, wherein the velocity is maintained constant, with a longer inner section of twenty-foot

diameter, wherein the velocity regularly increases with respect to distance along its axis. Diffuser sections are situated at the inner end to reduce the velocity to that existing in the Welland River section with as little loss as possible.

The slot on the upstream side of the tubes varies in width from one foot at the shore end to four feet at the outer end, where the slot ends. A restricted section, shaped somewhat like a bathtub, forms a mouthpiece for each tube, its function being to give the required initial impulse to the sucking slot.

The head at any point on the tube, causing flow through the slot, is the resultant of three components (a) the initial loss due to the primer, (b) the total of the induced losses due to the increments of angular flow through the slot, and (c) the total cumulative friction head loss in the tube, including velocity head.

The designed rate of total inflow through each slot is 2500 cubic feet per second along the axis of the tube. The rate of inflow per running foot of slot has not been chosen uniform, however, because the river naturally feeds more water at the outer end of the tubes than nearer the shore. This variation has been chosen in the ratio of four at the outer end to three at the inner end of the slot, which agrees with the natural flow distribution under present river conditions. The total head loss in each gathering tube to the end of the diffuser, with a flow of 2500 cu. ft. per sec. in each tube, will be only three-tenths of a foot.

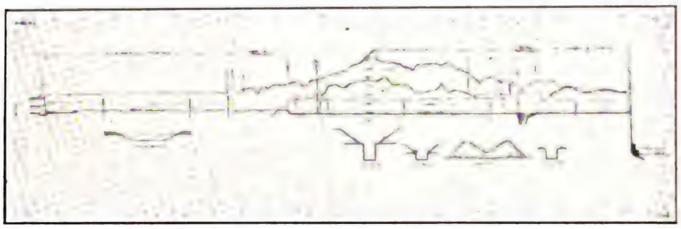


Fig. 3—Profile of Canal

During the greater part of the year, when no ice is running in the river, the intake gates of both surface and submerged intakes will be open. The navigation channel will also be open and the velocity through the intake at any point will therefore, be very low, so that the head loss under ordinary conditions will be negligible.

The Canal

For a great many miles above its mouth the Welland River is a sluggish stream, meandering slightly in a depression that can hardly be called a valley. This stream for four and a half miles forms the first reach of the canal, and its low banks provided a suitable disposal area for much of the material excavated in the process of straightening and deepening the channel. The radius of curvature of some of the bends is increased in the new alinement, but in the main the old channel location is followed. The velocity under full-load conditions will be low, being limited by the scouring velocity for the clay soil through which the improved channel is cut. The canal leaves the river channel near the crossing of the Michigan Central Railway and turning through a deflection of 28 degrees takes a course almost due north for over three miles. The ground surface (Fig. 3) rises fairly uniformly until the crossing of Lundy's Lane is reached. The elevation here is over 660 feet above sea level or 100 feet above the water surface of the intake. The earth overburden is quite heavy (Fig. 4) for the whole of this portion of the canal, the bottom grade of the canal cutting the rock surface one mile from the Welland River. The maximum rock elevation which is 604, is beyond Lundy's Lane and therefore not coincident with the maximum earth surface elevation but the profiles of rock and earth surface are roughly parallel to each other. Just beyond Lundy's Lane there is the maximum bend with a deflection of 51 degrees,

Fig. 4—Canal in Rock Section

Fig. 5—Canal Showing Bridges

and at intervals of a little over a mile each, two other bends of 27 and 31 degrees. The earth over-burden continues fairly uniform (Fig. 5) for three miles beyond Lundy's Lane until Bowman's Ravine is reached.

Fig. 6—Looking North— Canal at Whirlpool Section

Here, both rock and earth surfaces fall sharply to an elevation far below the grade of the finished canal. The ravine here is apparently an old river channel through which the Niagara River in preglacial times flowed toward Lake Ontario. At the time the construction started this was the course of a small stream having its outlet at the Whirlpool. The ravine crossing, Fig. 6, is made on a fill and the ravine itself proved a convenient disposal area for about 1,500,000 cubic yards of excavated material.

Where the canal section again enters the rock cutting beyond the ravine, the earth over-burden becomes very light, in some places amounting to only a foot or so. Two deflections are made in the remaining two miles of the canal, one of 33 and one of 47 degrees. A quarter mile beyond the second of these curves the forebay (Fig. 7) is reached.

The Design of the Earth and Rock Sections. Long continued investigations were made of available information on roughness factors for large canals in earth and rock with and without concrete lining. One of the conclusions reached was that Kutter's formula should be used. The roughness factors used in the hydraulic studies were 0.035 for the river section and 0.012 for the concrete lined rock section.

Forty-eight hundred feet from the Welland River the rock surface cuts the bottom grade of the canal. The shape and size of the channel begins to change here, a transition to the rectangular cross-section of the rock section taking place.

A thorough study of excavating machinery and methods that was carried on in 1916 and 1917, indicated the economy of using heavy equipment capable of loading the spoil from the bottom of the cut into cars at the surface. A cut at least forty-eight feet in width was necessary to permit these large shovels to work and economy studies indicated that the saving effected by the large shovels would compensate for any other losses that the wide cut occasioned.

Economy Studies. The procedure in determining the economic proportions of the canal will be outlined briefly. It is essential that the canal should carry full quantity of water required under the lowest conditions of water level in the Niagara River. A series of canals was designed each of forty-eight-foot width and capable of carrying the required supply of water with uniform flow and with low water in the Niagara River at Chippewa. The first of the series was of such a depth that the velocity would be four feet per second and the designed slope of the bottom and water surface was the requisite slope for uniform flow, the others being designed for higher velocities.

The cost of each of these canals was figured and a curve plotted between low water velocity and cost. From this curve the tangents were scaled for various low water velocities. For low velocity the canals will be deep and therefore costly. For very high velocities the canals will be shallow but the slope so steep that the cost will be greater than for moderate velocities, the canal of minimum cost being for a velocity intermediate to the greatest and least investigated. The canal of minimum cost, however, is not necessarily the most economical. Enlargement will reduce the friction loss and consequently increase the head and power output at a cost which up to a certain point is both justifiable and economic. The determination of the economic size is based not on low water but on the mean water conditions. For each of the canals already designed, the profile of the water surface corresponding with mean water level in the Niagara River is computed, thus determining the friction loss

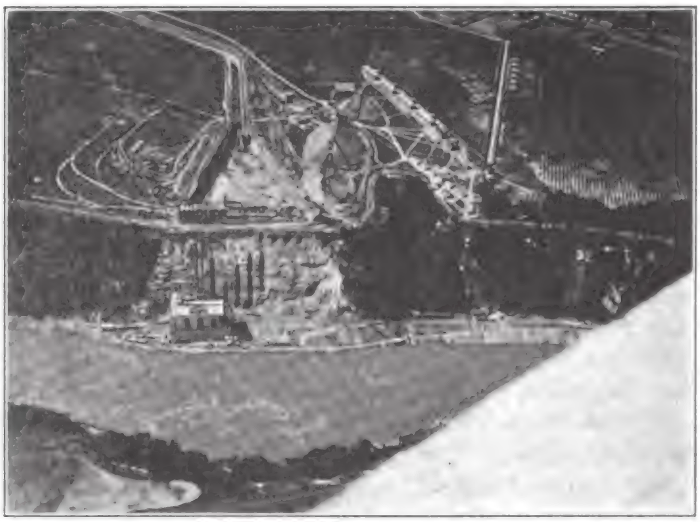


Fig. 7—View of Forebay and Power House

and lost power at mean water. Tangents were scaled from a lost power curve plotted from these results and were divided into the tangents from the lost power curves for each low water velocity. The dividend in each case is the cost in dollars per horse power of

the power gain at the particular velocity to which the result applies. These dividends are now plotted against low water velocity, constituting an "economy curve" from which the economic velocity may be selected.

Slight changes in the head give increases in power without appreciable change in operating or maintenance costs, and the only essential charge against power gained by slight enlargements of the canal is the interest charge on the cost of enlargement. The economic velocity, therefore, is one corresponding with the total cost per horse power on the economy curve considerably higher than the total average cost of the whole development.

Control Works. A control gate (Fig. 8) is located at station 97+00 which is near the beginning of the rock section. This is an electrically operated Stony sluice of forty-eight foot clear span, the full width of the rock section. The use of two gates with a central pier was considered, but the single gate was found to be the most advantageous, as it provided an unobstructed waterway with a consequent reduction in friction losses. The gate, which is supported on steel towers with a concrete substructure, weighs approximately 100 tons, and is provided with two hoisting mechanisms and two counterweights. The gate when at the top of its run is sufficiently above the water surface in the canal to permit a tug to pass beneath.

Fig. 8—Control Gate

Whirlpool Section. Bowman's Ravine west of the whirlpool was crossed on a rock fill, the cross-section of the canal being changed from a forty-eight-foot rectangular section to a trapezoidal section with ten-foot bottom width and side slopes of one vertical and one-half-to-one horizontal. This cross-section was designed to be as large as the rock section at the extreme minimum water level at which operation of the generating station could take place, and of course, the trapezoidal shape gives it greater area than the rectangular for any water surface elevation greater than this. The whirlpool section is lined with concrete, carrying considerable reinforcement to protect the lining, in the event of settlement of the fill. It was also anticipated that should the canal be emptied at any future time, this lining would not withstand the inward pressure of the water with which the supporting rock fill would be saturated, so vents of sufficient size to drain the fill as quickly as the water could be drawn down in the canal, were provided near the top and bottom of the channel. These vents are protected with light wooden covers, which will be dislodged under a comparatively small excess of inward pressure.

Concrete Lining. Economic considerations prompted the lining of the canal with concrete. The height of the lining was fixed slightly lower than the profile of the water surface existing when the load conditions on the plant are a maximum and the Niagara River flow is a minimum. Thus, at all times the lining will be protected by submergence against the action of frost. The thickness of the lining varied with the rock over-break but averaged about 20 inches, and where necessary, steel dowels were used to anchor the concrete lining to the rock face.

It was held that extreme smoothness of surface was not the only determining factor, but that precise alinement is also a most important element in the reduction of hydraulic losses. Great care was taken to obtain a smooth surface by the use of steel forms, and a positive and rigid method of form setting was devised, which insured almost perfect alinement. The results obtained were very excellent, and it is expected that when opportunity offers to test experimentally the efficiency of lined section of the waterway, extremely low roughness factors will be realized.

The Forebay. The kinetic energy of the water at the end of the canal, and at entrance to the forebay was too great to neglect in the design. Necessarily, in the forebay the velocity of the water will be so greatly reduced as to make its velocity head negligible, and some means therefore had to be found to regain the energy in the water as its velocity decreased. The same difficulty is experienced here as in any transition in which velocity is being reduced, namely, that the stream lines tend to follow paths of their own course, unless the design is very carefully worked out and the angle of divergence properly fixed.

A great mass of experimental data on diverging tubes for air and water is available, indicating that a

ten-degree angle of flare is the most efficient. In order to confirm for this particular case the conclusions arrived at from other experiments, a model of the forebay was built in the Hydraulic Laboratory of the University of Toronto, and tried out with nineteen transitions of various angles and lengths. These experiments confirmed the conclusions reached from other available data, and also provided, in their quantitative results, a basis for the economic design of a transition that would cost no more than was justified by the gain in power from reclaimed head. These experiments involved measurements of extremely small differences of water level, necessitating observations to thousandths of an inch as the velocities in the model were quite low—only one-twelfth of the corresponding velocity in the full-size structure. Notwithstanding this condition, the results were, with very few exceptions, quite consistent and resulted in the design of the "diffuser" structure inserted in the forebay transition, providing two entrance passages into the forebay, each with a diverging angle of ten degrees (Fig. 9). It consists of

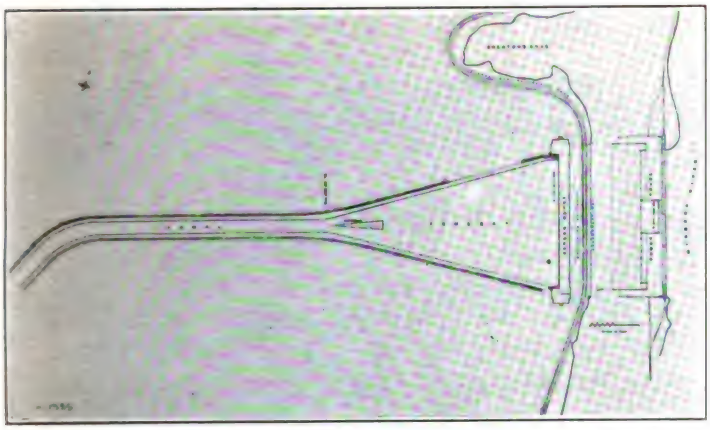


FIG. 9—GENERAL PLAN OF FOREBAY AND POWER HOUSE

a wedge-shaped structure 221 feet long and 37 feet wide at the downstream end. The sides are vertical, straight and smooth and are carried 28 feet above the bottom of the forebay. An opening 16 feet by 20 feet in the end wall assures approximately equal pressures on both sides of the walls.

Through this expedient, the high velocity at the end of the canal is gradually reduced and its kinetic energy recovered, with the result that the elevation of the water in the forebay beyond the deflector will be higher than at the mouth of the canal. For a flow of 15,000 cubic feet per second, and mean water level at Chippewa, the reclaimed head amounts to approximately one foot.

SCREEN HOUSE

At the lower end of the forebay, and serving as a dam for the same, is located the screen house. This structure forms the entrance, and the control, for the penstocks. The entrance to each of the main penstocks is a modified bellmouth consisting of three openings 12 feet 8 inches wide and 29 feet high at the rack supports. These three openings gradually converge into one opening 16 feet in diameter at the point of connection to the penstocks. In designing these water passages particular care was given to the securing of smooth stream lines and consistent changes in velocity. The bell-mouth entrances are sealed by a concrete curtain wall extending down to elevation 542.0 which gives a depth of 28 feet above the floor of the forebay. Immediately behind the curtain wall, steel-lined gate checks are provided to support structural steel gates. These provide a means of unwatering in case it is necessary to get at the lower sections of the racks, or for inspection of the penstocks. The dividing of the intake into three waterways was done in order that the spans for the gates could be made of convenient size and to permit the use of racks of a somewhat new design. The racks, which consist of three-inch by three-eighths-inch bars on edge, at five-inch centers, are fastened rigidly to a structural steel supporting frame held in checks in the concrete walls. The whole of the rack structure is removable and they are split horizontally into two sections for convenience in handling. A specially designed rack follower with an automatic latch arrangement is provided to facilitate the removal of the racks, the bottom section being a considerable distance below the floor of the screen house. The bars and the supporting structure of the racks are designed to withstand a head of 10 feet with a stress of 20,000 pounds to the square inch in the steel. This type of construction removes the danger of a serious shutdown due to the collapse of rack structures, as in the event of blocking by ice or other foreign matter the failure of one section would immediately relieve the others. The broken section can then readily be replaced with a spare one without serious interruption to operation.

A trash trench of liberal dimensions extends across the bottom of the forebay immediately in front of the screen house piers to collect any debris or foreign material which may travel along the bottom of the forebay. The piers dividing the main unit entrances are 6 feet in thickness, while the two intermediate piers in each unit are 3 feet thick. The main dividing piers are designed for full water pressure on each side in order that any unit of the intake may be unwatered while the adjacent units are in operation. An opening in the main floor immediately behind the racks provides a means of disposal of trash into a trough, which empties into the ice chute.

The screen house, as constructed, provides for nine main units, a service unit and an ice chute, and is arranged so that a further unit entrance may be added at the north end.

The entrance to the service unit is similar to the main unit, except that it consists of one bay only, and the entrance to the penstock itself is a true bell-mouth instead of the sectionalized transitions in the main unit entrances. The ice chute bay has a clear width of 25 feet and is provided with a sluice gate of the Stony type, which is lowered to pass surface water

carrying ice. After passing the gate, the water and ice enter a 10-foot diameter concrete pipe and passing down the cliff, out beneath the power house, empty into the Niagara River. Stop log checks are provided ahead of the gate for use in an emergency, or for inspection purposes.

The screen house is located close to the edge of the escarpment, only a narrow ledge of rock being left between it and the gorge. Owing to the disastrous results which would follow a failure, the screen house substructure was designed to resist the full head exerted by the water in the forebay without any assistance from the adjacent rock. The superstructure is built with reinforced concrete walls and roof with a structural steel framework, and is equipped with an electrically operated traveling crane of 25-ton capacity for handling the racks and gates. At the south end of the screen house proper, an enlargement of the building provides for administration offices, and entrance to elevator to the tunnel giving access to the generating station.

Penstocks

From the screen house, the water is carried to the turbines in steel plate penstocks. The main unit penstocks are 16 feet in diameter for approximately two-thirds of their length, and are then reduced by a taper section to a diameter of 14 feet. The accompanying illustrations show the excellent alinement of the penstocks, there being only two bends, one located at the top and one at the bottom. These elbows are held in massive concrete anchor blocks, the one at the upper bend forming a foundation for the piers supporting the sidewalk and roadway along the edge of the escarpment.

Each penstock ring is made up of two plates with longitudinal joints on the horizontal center line. These joints are all double butt joints, varying from double riveted at the top to quadruple riveted at the lower end. The circumferential joints are also single butt, double riveted with the butt strap on the outside. The longitudinal joints are calked on the inside, but the circumferential joints are made water-tight by electric welding. This type of circumferential joint gives a very much better alinement to the inside of the pipe than can be obtained with the usual outside and inside course with lap joints. In designing the penstocks a stress of 12,000 pounds to the square inch was used, this figure being taken to provide for the exigencies of corrosion, fatigue, suddenly applied loads, and other indeterminate or unknown contingencies. The internal pressure, used for design purposes, was taken to be the static head, plus the pressure rise due to a complete closing of the turbine gates in $1\frac{1}{2}$ seconds. This increase in pressure was taken as a maximum at the turbine gates and varying uniformly to zero at the racks.

The thickness of the plates varies from one-half inch at the top section to one and one-quarter inches at the lower section, while the longitudinal butt straps are one-half inch thick with two rows of seven-eighths inch rivets for the lightest joint, and fifteen-sixteenths-inch thick with four rows of one and three-eighths-inch rivets for the heaviest. The efficiency of the longitudinal joints at the heavy section is approximately 85 per cent. In the erection of the penstock, a new departure was initiated in the use of electric rivet heaters; by this method a consistent and close range of temperature was possible so that burnt rivets were very rarely encountered.

The penstocks are covered throughout their entire length with a concrete envelope, having a minimum thickness of 24 inches, which protection will, it is believed, greatly increase the life of the steel pipes.

The penstock for the service units follows the same alinement as the main penstocks and has a diameter of five feet. As friction loss in this pipe was not such an important factor, lap joints and inside and outside courses were used.

Generating and Transformer Station

The generating and transformer station (Fig. 10) is located below the escarpment and close to the River's edge. As will be observed from the cross-section drawing, the station extends about one-half the distance to the top of the escarpment. The structure required to house five main units and the service equipment is 350 feet long, and ultimately this length will be doubled. The substructure is of massive concrete construction carried down to rock foundations, and provides chambers and tunnels for housing and giving access to various kinds of apparatus. The superstructure consists of a structural steel frame work with reinforced concrete floors and roofs, and concrete, brick and tile walls and partitions.

Fig. 10—View of Power House
From American side of river.

The location of the transformer and switching portion of the plant on the top of the escarpment was considered, but owing to the difficulties in carrying the current at 12 kv. from the generators to the transformers up the cliff; and to operating advantages in having a combined station; also to the space between

the generator room and the cliff being sufficient for the purpose, the decision was made to have the building to house the transformers and switching equipment combined with the generator room. It will be noted from the cross-section of the plant (Fig. 10A) that the layout of electrical equipment accommodates itself to the 60-degree slope of the cliff.

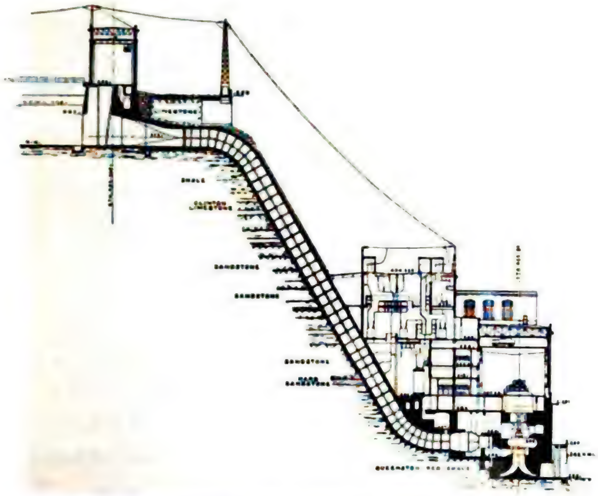


Fig. 10A—Cross-Section of Power House on Center Line of Main Unit

The steel columns are spaced longitudinally 26 and 24 feet alternately starting at the south end. The strength of the generator room steel was primarily determined by the necessity of providing cranes to handle the generator rotors which weigh about 300 tons each. The structural steel was so designed that it could be erected and the crane operated before the concrete walls were poured.

To guard against flooding due to the river level rising, the walls are designed to resist water pressure up to elevation 300, which is 16 feet above the base of the generators. No openings which might admit water from the river were permitted below this elevation, although temporarily a railway track is brought in at the south end at elevation 284, and is protected by stop logs.

The illustrations show the general design of the building. Some features which may be mentioned are: the arrangement of the generator cooling air intake ducts, which are carried up in the east wall between the columns to above elevation 300, where openings are provided to admit air either from outdoors, or from the interior of the generator room, an arrangement which takes up no floor space; the location of the generator room main floor at the top of the generator frame, a construction which provides space at small cost for the exhaust air ducts, fans, generator field equipment adjacent to the unit, and still allows a clear space around the generator on the main floor; the large steel sash windows in the generator room which are 21 feet in width by a total height of 38 ft. 4 in.; longitudinal tunnels in the substructure for handling turbine runners, and for piping; a longitudinal room, centrally located, for all conduit runs for control and instrument cable, with a corridor immediately above it the full length of the building; the location of control room over generator room at the center of the completed plant; provision of separate rooms for each 12-kv. oil circuit breaker; and particularly the symmetrical location of all main equipment for each unit—governors, transformers, oil circuit breakers, reactors, fans—in the 50-foot longitudinal space in which the turbine and its generator are situated.

The floor at the top of the generator frame materially reduces the unsupported height of the main crane columns, and does not affect the elevation of the crane rails, as the height of the crane is determined by the height of generator frame and shaft.

Access to the building from the main roadway and the electric railway on the top of the cliff is provided by the elevator in the administration end of the screen house, and a tunnel from the bottom of the elevator shaft to the power house floor on elevation 346 at the south end (Fig. 11).

In general, all plant services are provided in the southerly 75 feet of the station. In this area are located the sump pumps and motors, the air compressor, the service generators, transformers and switchboards, erection space, main station elevator, maintenance shops and stores, lubricating and insulating oil plants, battery rooms, a fully equipped hospital room, also kitchen and dining room and offices. The intention

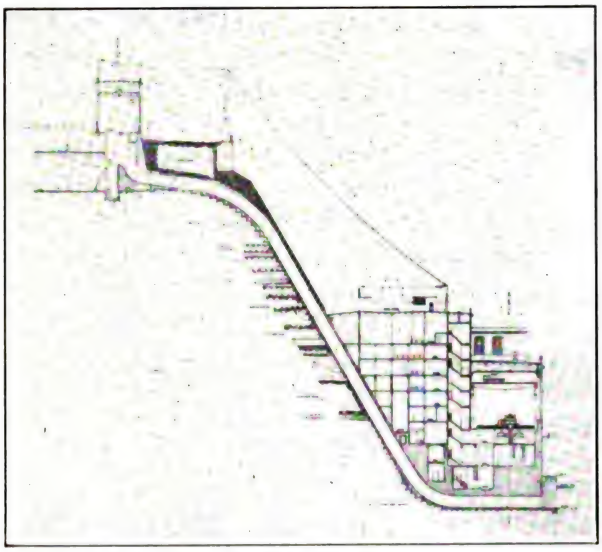


Fig. 11—Cross-Section of Power House Near South End

is to duplicate nearly all these services in the extreme north end of the ultimate stations.

Permanent railway connections are provided by a track built along the river at the bottom of the cliff from the generating station to the Michigan Central Railway at the village of Queenston. A railway track is carried across the river side of the station building

on an extended portion of the substructure to give access to the area to the south.

A 300-ton crane consisting of two separate units each having a capacity of 150 tons is provided in the generator room for handling generators, transformers and other apparatus. When the crane is to be used in lifting the generator rotor, which is the heaviest piece, an equalizer beam is used. This crane is supplied with a-c. motors and control.

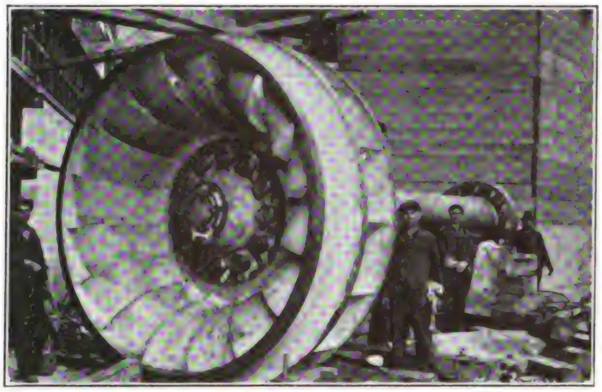


Fig. 12—Turbine Runner

Electric hoists are located throughout the station to facilitate the handling of equipment.

The entrance elevator, from screen house to entrance tunnel, operates at a speed of 450 feet per minute, and is equipped with a 25-cycle, 550-volt, three-phase, variable-speed motor of the commutator type with brush shifting gear. The main elevator in the power house is in the southerly portion of the building and serves all floors. It operates at a speed of 350 feet per minute and is equipped with a two-speed, 25-cycle, 550-volt, three-phase induction motor. An automatic elevator located near the control room for the use of the operators, is also operated by a 25-cycle, 550-volt, three-phase induction motor.

TURBINES

Each unit has a capacity of 55,000 brake h. p. under 305-foot head and the section through the power house shows clearly the general arrangement. The draft tube on No. 1 unit is of the common curved type modified at the elbow, while each of the other units is equipped with a Moody spreading tube. In the design of these units care was taken to insure good lubrication for the gate stems and to assure that all wearing surfaces were well greased. The use of labyrinth seals on the runner rims (Fig. 12) cuts down leakage to a minimum. It will be noted on the section that the top portions of the draft tubes are of cast iron and these are so arranged that they can be lowered to facilitate the removal of the runner from below, thus dispensing with the necessity of dismantling of the generator. Owing to the presence of a considerable amount of sand in the water during periods of flood, and by reason of dredging operations in the upper canal, a pressure sand filtering plant has been installed to filter all water supplied to the lignum-vitae bearings to prevent scoring of the turbine shaft. The lignum-vitae bearings themselves are about six feet in length and in order to ensure lubrication over their entire length the water is admitted both at the middle and top of the bearing. A flow meter, with an indicator and an alarm light, is connected to the bearing water supply to guard against any stoppage of the flow continuing long enough to injure the shaft or bearing. The longitudinal passageway on elevation 264 gives access to the turbine bearings, gate stems, servomotors, (Fig. 13), governors and filters.

Air brakes, which act against the underside of the generator rotor, are provided to bring the unit to rest quickly in case of shutdown.

JOHNSON VALVES

The lower end of the main penstock terminates in a 14-foot Johnson valve, the outlet end of which is 10 feet in diameter and connects to the turbine casing by several sections of cast steel pipe. While this type of valve is too well-known to require any description, the method of control is worthy of note. This is accomplished through three 8-inch Johnson valves, which are in turn operated by pistons in cylinders under penstock pressure controlled by a three-way plug valve. When opening the valve to fill the scroll case, it is necessary to build up the pressure in the latter, in order to balance the pressure on the two sides of the plunger. The operation of the valve is so arranged that this is carried out automatically by a series of oscillations of the plunger, as soon as the control handle has been thrown into the opening position. In closing, the motion of the plunger is retarded near the end of the stroke to prevent an excess rise in pressure, due to too sudden closing, and also to protect the plunger seat against shock. The control is so arranged that the valve will close automatically in case of a break in the scroll case, and it is also provided with a remote hand control so that it may be closed, if necessary, from the control pedestal on the main operating floor.

Fig. 13—View of Turbine Deck

Access to the valve is from the floor on elevation 264,

the valve being located in a chamber which provides space for dismantling the valve.

The five-foot service penstock terminates in a steel plate *Y*. The two legs are each equipped with a 36-inch Johnson valve for each service turbine.

Governors

The governor system for the main units uses filtered water containing one per cent of soluble oil. This is supplied to the governor at from 150 to 200-pounds per square inch pressure from two motor-driven centrifugal pumps which feed into an accumulator tank for each unit. The return fluid from the servomotors is carried back through a return main to two concrete tanks so arranged that one tank may be emptied and cleaned while the other is in operation. It had been found in other installations, where a central pumping system capable of handling the completed plant was initially operated to supply only one or two units, that difficulty was experienced owing to the large capacity pumps heating up the small amount of fluid in circulation. To avoid this, a small capacity pump was also installed to supply governor pressure during

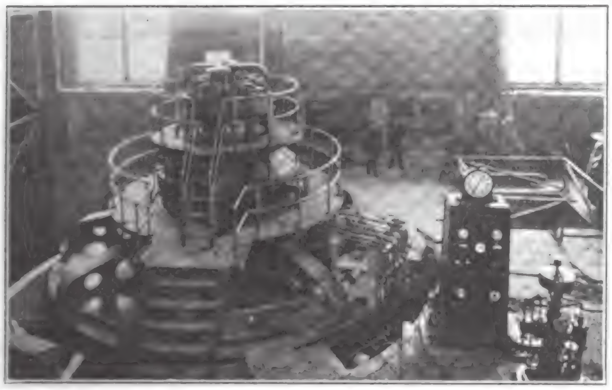


Fig. 14—No. 2 Generator Showing Control Pedestal and Governor Head

the early stages of operation, and to be held afterwards in reserve for an emergency. To guard against a shutdown due to the failure of the governor pumps, an emergency connection has been provided to pass direct penstock pressure into the governor system header. This permits the governors to operate on penstock pressure, at any time that the pumping system is out of service, and has already been called into service since the first two units were placed in operation.

Owing to the very small ratio of length of penstock to head (about $1\frac{1}{4}:1$) and the large flywheel effect of the generator rotors, the regulation of these units is a comparatively simple problem.

Generators

The present five units are each rated at 45,000 kv-a., 80 per cent power factor, 12,000 volts, three-phase, 25 cycles at 187.5 rev. per min. They are capable of being operated continuously at 49,500 kv-a., with either voltage or current 10 per cent in excess of the rated values. The type is vertical (Fig. 14) with direct-connected shunt-field commutating-pole, 250-volt, 150-kw. exciter. The over-all efficiency of the generating units is slightly in excess of 97 per cent at 80 per cent power factor. The thrust bearing is designed to support a load of one million pounds, which is slightly in excess of the weight of the rotor plus the hydraulic thrust imposed by the turbine. Upper and lower guide bearings are provided the latter on account of the length of shaft and to keep the generator a self-contained unit.

The quantity of air required for cooling is 120,000 cu. ft. per minute. It is interesting to note that the weight of air passing through the generator every $2\frac{1}{2}$ hours equals the total weight of the generator, namely 1,400,000 pounds. The units are completely enclosed, the air being drawn either from the outside of the generator room, or from both, and discharged through ducts into the atmosphere or to the different sections of the building for heating purposes. With five units in operation at rated load, there will be available for heating the building 5400 kw., which corresponds to 1.2 kw. per 1000 cubic feet of building contents. This amount of heat should be ample for heating the building at all times.

The maximum observable temperature which any portion of the unit will attain under rated conditions as obtained by thermocouples will not be in excess of 105 deg. cent. with 40 deg. cent ambient air. The temperature as obtained by thermocouples is indicated on the control pedestal adjacent to the generator, and also in the control room.

Units Nos. 1, 2 and 3 are all of the same make, having a rotor with cast steel spider and laminated built-up sheet steel rim, dovetailed to the spider. These three units have upper and lower bearing brackets of cast iron, and are provided with the Kingsbury thrust bearing. Armature windings are insulated in slot portions with sheet mica insulation ironed on, whereas the end portions of the windings are insulated with mica and varnished cambric taping. The stator is divided vertically into four 90-degree sections.

Units Nos. 4 and 5, being made by a different manufacturer, have a rotor made up of seven cast steel sections, five of which carry the pole pieces, the other two, one above and one below, being provided for additional flywheel effect. Upper and lower brackets are of cast steel and a spring supported type of thrust bearing is used. The armature coils are insulated throughout with mica tape. The stator is divided into three 120-degree sections.

The flywheel effect of each unit is 21,500,000 $W R^2$. The rotors are required to stand an overspeed of 185 per cent of rated speed. Insulation tests of 30,000 volts on armature and of 2500 volts on field and exciter are specified.

The over-all diameter of these units is 25 feet, the diameter of rotor over pole faces being 18 feet

approximately. The shafts are 30 inches in diameter in the guide bearings and are provided with flange at lower end for bolting to corresponding flange on turbine shaft. The shafts are hollow with 8-inch diameter bore and are 30 feet 3 inches in total length. The over-all height of generators above the generator floor (elevation 284) is 26 feet 10 inches, thus above the main floor (elevation 297) only the top of the frame and the upper bracket, thrust bearing housing and exciter are visible (Fig. 15).

The weight of the complete generator is 1,400,000 pounds, that of the rotor 615,000 pounds. The largest piece to be handled by the cranes weighs 600,000 pounds.

Fig. 15—Interior View of Generator Room Looking North

Excitation

The principal source of excitation for each unit is the direct-connected exciter mounted above the generator. Each exciter has sufficient capacity to furnish excitation for one 45,000-kv-a. generator, and is rated at 150 kw., 250 volts. It is of the shunt-wound type with commutating poles and is especially designed for service with a generator voltage regulator.

The auxiliary source of excitation consists of a motor-generator set made up of a 250-volt 150-kw. shunt-wound d-c. generator, with commutating poles designed to carry the excitation of any one of the generators, and to work with the voltage regulator belonging to that unit. At present there is one auxiliary exciter set for five units, but in the completed station it is contemplated that there will be additional sets, each acting as a spare exciter for a group of machines. Each spare

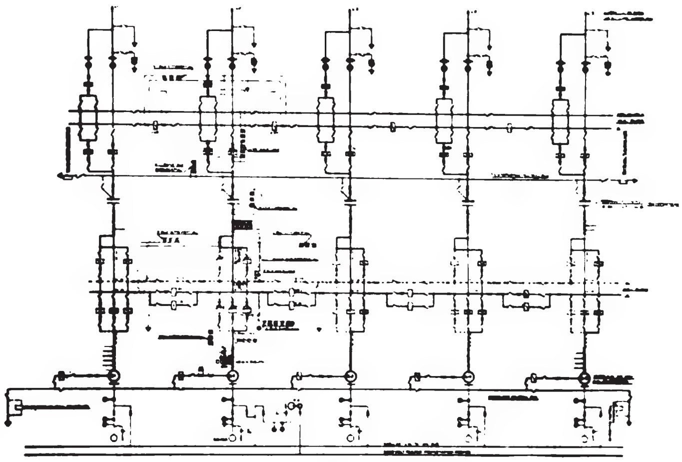


Fig. 16

exciter may be connected to its own bus, to which the field of any generating unit of its group may be connected as shown in the diagram (Fig. 16). The auxiliary motor-generator sets are driven from the 2200-volt station service system.

Fig. 17—45,000-Kv-a. Single-Phase Transformer

A voltage regulator of the vibrating relay type controls the voltage of each generator. This regulator is equipped with compensation to prevent cross currents

when units are in parallel on the 12-kv. bus, also with adjustable compensation for ohmic and inductive drop in transformer banks and lines. Each is provided with a device for maintaining a low maximum of exciter voltage in case of a drop of voltage due to short circuit,

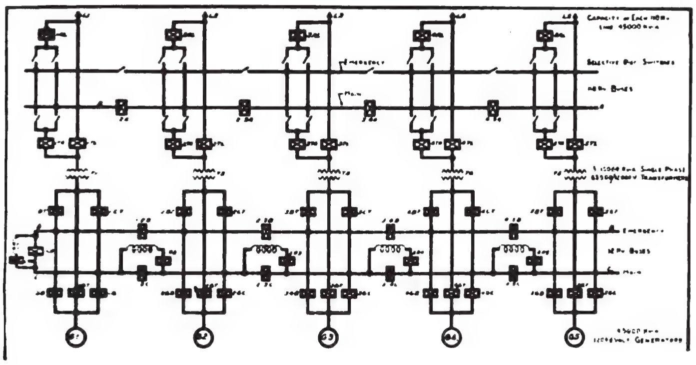


FIG. 18—QUEENSTON GENERATING STATION—WIRING DIAGRAM OF MAIN CONNECTIONS

also with a device for cutting resistance into the exciter field circuit to limit the voltage in case of overvoltage due to overspeed or other causes.

No main generator field rheostats are used.

TRANSFORMERS

These are of the shell type and are individually rated at 15,000 kv-a., 25 cycles, 12,000/63,500/76,200 volts at 80 per cent power factor. There will be five banks of three, connected $\Delta - Y$ to give 110 to 132 kv. at rated load. The guaranteed efficiency at 80 per cent power factor is 98.25 per cent. The quantity of oil required for each transformer with its expansion tank is approximately 6500 Imperial gallons, the weight of the complete transformer is 100 tons. The over-all height is 28½ feet, and diameter of the tank is 9½ feet (Fig. 17).

Maximum observable temperature rise is specified at 50 deg. cent. with an observable temperature rise of 55 deg. cent. under a 10 per cent overload, above ingoing cooling water temperature of 25 deg. cent.

Insulation tests are 280 kv. and 33 kv. on high and low-voltage windings respectively.

The main tanks are of boiler plate with plate bottoms and covers. The tanks are required to withstand an internal pressure of 150 pounds per square inch and also a vacuum equivalent to 24 inches of mercury. The main tanks will be completely filled with oil, the expansions of the oil being provided for in separate tanks, but provision is made in the height of the main tanks so that operation without the expansion tanks will be safe.

The transformers are mounted on roller bearing structural steel trucks set on rails on elevation 297 to the rear of the 12-kv. switching equipment. A track runway throughout the length of the building connects to a cross runway at the south end, which permits moving the transformers to a position under the generator room cranes.

MAIN CONNECTION DIAGRAM AND SHORT-CIRCUIT STUDIES

The main wiring diagram (Fig. 18) shows the electrical arrangement of the main apparatus. A generator, bank of transformers and a line is considered a unit, each with a normal capacity of 45,000 kv-a. It will be impracticable to dispose of the power in blocks of this capacity and grouping of units will be essential. For this purpose 12-kv. and 110-kv. busses are provided. The diagram shows a double 12-kv. bus, only one of which, however, that with reactors, is being installed, but space is being provided for the second or emergency bus, and this may be installed later if conditions warrant.

Extremely interesting studies were carried out to determine the mechanical, magnetic and thermal effects on conductors under normal and abnormal operation with different groupings.

In the analysis practically all possible conditions of operation were considered. A key diagram was prepared with symbols representing groupings of units.

Referring to Figs. 19 and 20, I, II, III or IV indicates that 1, 2, 4 or 8 generators are paralleled on the low-

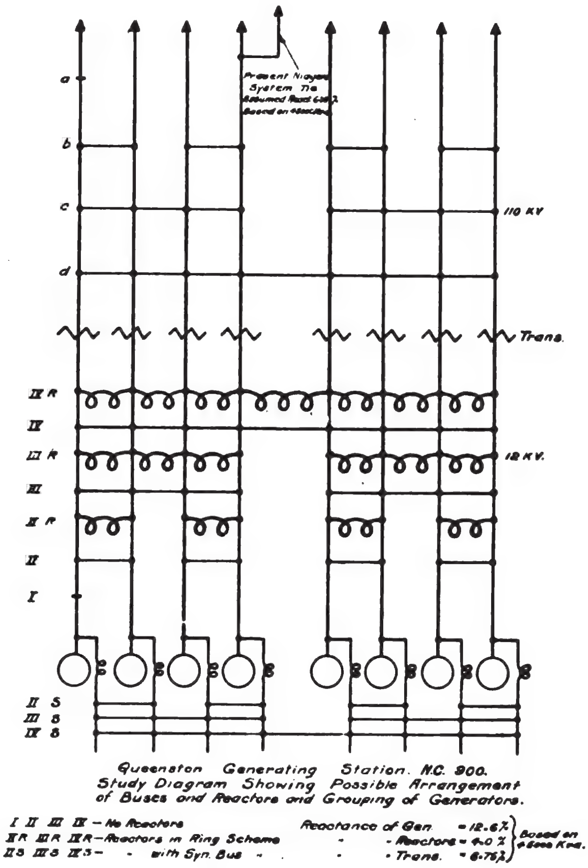


FIG. 19—DIAGRAM FOR SHORT-CIRCUIT STUDIES

voltage bus. If followed by *R* as II *R*, etc. the generators are paralleled through a reactor. If followed by *S* as II *S*, etc. the generators are connected to a synchronizing bus through a reactor. *a*, *b*, *c* or *d* indicates that 1, 2, 4 or 8 generators are paralleled on the high-

voltage bus, so the significance of III *R d* may be readily understood as two groups of four generators each connected through reactors on the low-voltage side and the eight units paralleled on the high-voltage bus.

The short-circuit values are given as the r. m. s. values of the first symmetrical wave of current times the normal voltage times square root of three.

From the studies it was found that the star bus

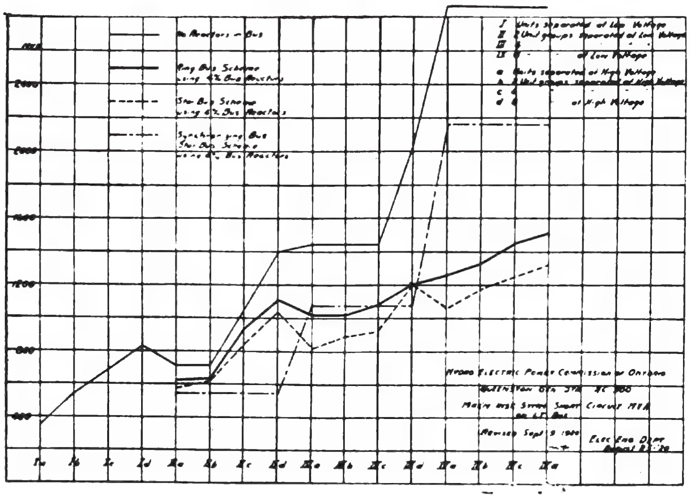


FIG. 20

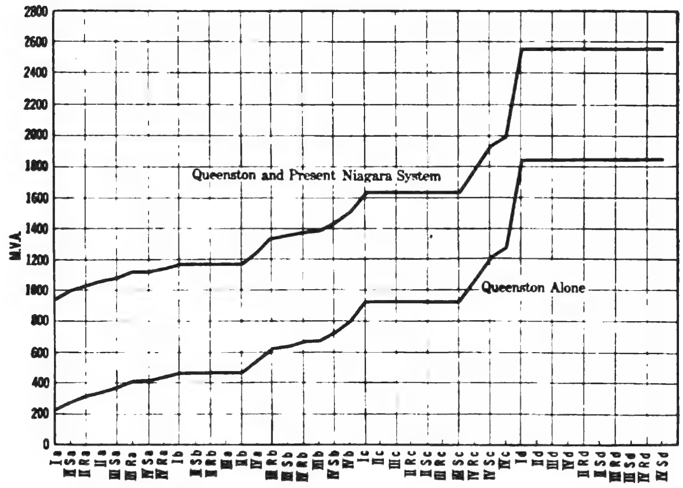


FIG. 20A—MAXIMUM SYMMETRICAL SHORT-CIRCUIT VALUES ON H. T. BUS

scheme had a slight advantage in so far as short-circuit currents are concerned over the ring bus scheme with not more than four generators in parallel, but with more than four generators in parallel the short-circuit currents on the star bus are considerably higher than on the ring bus.

With eight generators operating in parallel on the 12 kv. bus the r. m. s. value of the. first wave of the symmetrical short-circuit current may reach a value of 140,000 amperes with no reactors between generators. Using 4 per cent reactance (based on the capacity of a generator, namely 45,000 kv-a.) in bus reactors between the generators in the ring bus scheme 73,000 amperes would obtain and 104,000 amperes in the star bus if that scheme were used.

For the above short-circuit values (140,000, 73,000 and 104,000 amperes) the forces between the busses, spaced two feet apart, would be 5120 lb., 1420 lb. and 2870 lb. respectively per linear foot of bus. Fig. 21 shows the forces between the busses for both 24-inch and 45-inch spacing under different conditions of operation.

From these studies it was decided to install 5 per cent bus reactors between the generators and increase the spacing between the busses to 48 inches in order to reduce the short-circuit currents and mechanical forces to a minimum within the limits of available space. Further increase in the reactance between generators would cause but slight reduction in the short-circuit currents.

These curves were used as a basis in deciding upon the strength of bus supports to use and the rupturing capacity of the oil circuit breakers required. The oil

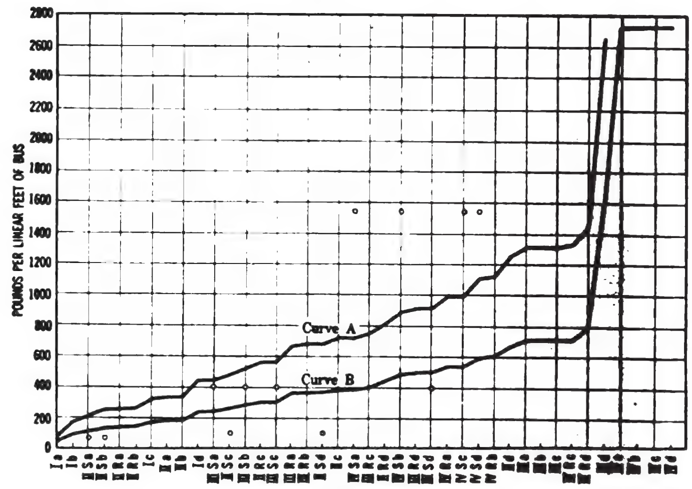


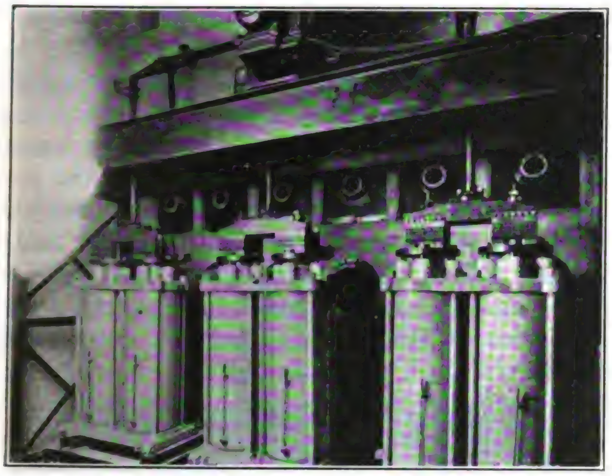
FIG. 21—MAXIMUM STRESSES ON L. T. BUSSES

circuit breakers which are used are suitable for operation under conditions at least as severe as IV *R c*.

CONTROL ROOM

The electrical control of the station is centered in the control room which is situated at elevation 361 above the generator room over units 4 to 6. A room approximately nine feet high underneath the whole control room permits control conduits to be brought in from the longitudinal conduit room and distributed to the various switchboards in an accessible and convenient manner. In the control room, the switch controls, indicators and dummy busbars are mounted on bench board sections, arranged in the general form of the arc of a circle. To the rear of the bench board are vertical panels carrying the necessary indicating instruments. Further back are the panels carrying the recording meters and relays, placed face to face. The completed switchboard will consist of bench board and panels for 9 or 10 units.

At each end of the main board is a five-panel board for controlling the main connections of the station service. This consists of bench board, instrument panels, recording meter and relay panels. Beneath each bench board and immediately behind each panel is a slot through the floor into the room below to permit easy installation and tracing of circuits.



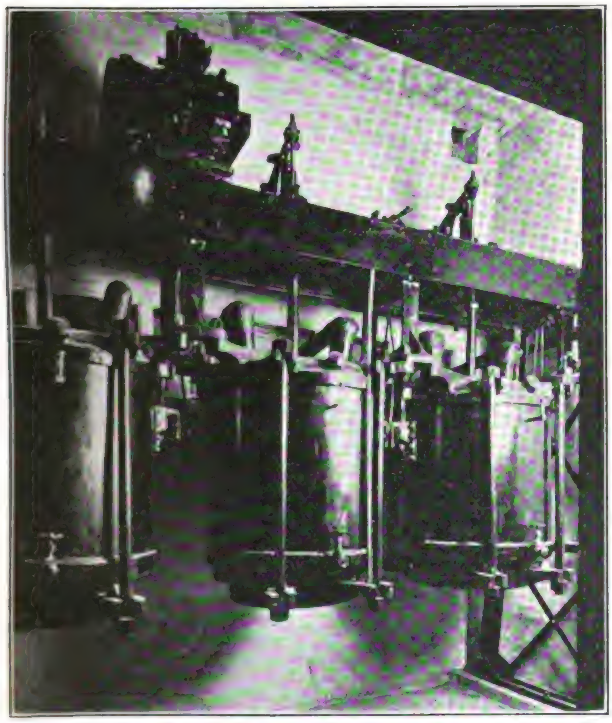


FIG. 22—12-KV 3000-AMPERE OIL CIRCUIT BREAKERS INSTALLED IN THEIR COMPARTMENTS

CONTROL PEDESTAL

On the main floor, near the governor of each unit (see Fig. 14) is a "control pedestal." This carries necessary hydraulic and electrical meters to enable the attendant to keep in touch with operating conditions affecting the complete generating unit. It also carries a telephone and signal indicators, connected to the control room, and a pull button switch by which the generator oil circuit breakers and field breakers may be tripped in case of emergency.

SIGNAL SYSTEM

For each unit, a dial-type signal system is installed between the control bench board and the control pedestal near the generator, by which instructions can be transmitted from the operator in charge to the generator attendant. This is supplemented by special telephone connections at each pedestal.

OIL CIRCUIT BREAKERS

Oil circuit breakers for 12-kv. service (Fig. 22) are rated at 15-kv., 3000-ampere continuous capacity. These are of two types, but the structural steel supports and general dimensions are such that they may be readily interchanged.

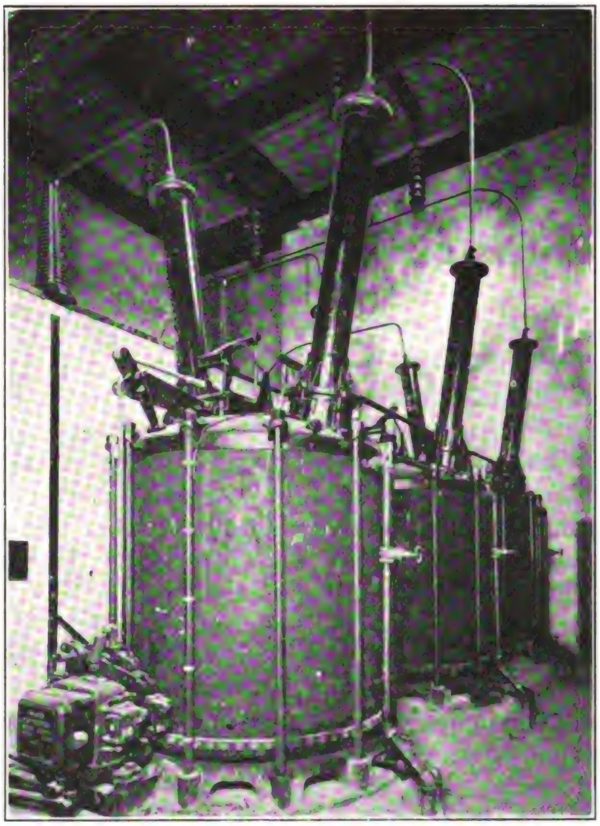


FIG. 23—135-KV. 600-AMPERE OIL CIRCUIT BREAKER

One type, used principally in units 1 and 2, is solenoid-operated, and has one heavy 36-in. diameter steel tank per pole. Each pole has contacts of inverted brush type with two breaks in series, which can readily be increased to four if necessary. Rupturing capacity is obtained by using large amount and head of oil in a very strong retainer. This breaker is guaranteed to rupture any short-circuit current obtainable with the plant connected in combination IV *R c*. Insulation will withstand 80 kv. for one minute.

The second type, used principally in units 3, 4 and 5, is motor-operated with two grounded tanks per pole. The arc is broken in oil in a very strong explosion chamber surrounding each arcing contact, arranged with baffles to shoot a stream of cool oil under pressure across the path of the arc. The main contacts of the wedge

and finger type are in air. This breaker is guaranteed to rupture any short-circuit currents obtainable under combination IV *R d.* Insulation will withstand a 55-kv. test for one minute.

Oil circuit breakers for 110-kv. service are rated at 135-kv., 600-ampere continuous capacity. They are of the solenoid-operated type with one tank per pole of heavy construction. In each pole there are four breaks in series, each break having a special quick break feature to increase the rupturing capacity. Each breaker is guaranteed to rupture any short-circuit current obtainable with combination IV *R c.*, and will withstand a test of 280 kv. for one minute. Bushings will withstand 350 kv. for one minute.

FIG. 24—12-KV. BUS INSULATOR

The control circuit voltage for operation of all breakers is 250 volts d-c. All breakers have ventilated tanks.

The 12-kv. circuit breakers are installed in individual rooms on two floors between the generator room and the transformers, with the main busses occupying an intermediate floor. These rooms are ventilated to the generator air discharge shaft. The leads from the breakers are carried through the wall at the rear through porcelain bushings, this giving a minimum of connecting material in these rooms.

The 110-kv. breakers (Fig. 23) are located on one floor at elevation 346, the breaker on the direct circuit from transformer bank to transmission line being separated entirely from all other breakers by walls. The breakers for each unit group connecting to the busses are in one room which has walls around all floor openings to prevent spread of oil.

Every switch room is drained into the general drainage system, and the doors to the rooms are provided with master-keyed locks. A designation symbol for every breaker is in use by which each breaker and its position in the connection may be readily identified.

12-KV. BUS AND CONNECTIONS

The results of the short-circuit current study showed that a strong construction would be required for the 12-kv. bus and connections from the generator terminals to the transformer terminals. The combination of the 3000-ampere normal current capacity adopted, with the mechanical strength required, made this bus structure a unique problem. From consideration of this, it was decided that no cable would be used on any of these 12-kv. connections.

The spacing of the phases finally adopted was 48 inches for the main bus, breaker and transformer connections and 37 inches for the generator leads to the bus. These spacings with a calculated short-circuit current having an assymmetrical peak of 170,000 amperes give maximum forces of 485 lb. per foot for 48-inch and 630 lb. per foot for 37-inch spacing.

It was decided that a single-unit bus support to resist a force of 10,000 lb. applied at the bus clamp should be obtained. This would allow a spacing of supports along the bus of about 5 ft. giving a factor of safety of 3 on the support under maximum load conditions. A single-unit porcelain bus support of smooth surface, with cast iron hardware cemented on, and having an ultimate strength of 10,000 lb. in cantilever (applied at the center of the bus) and an 80,000-volt, 25-cycle, flash-over, was finally obtained (Fig. 24).

FIG. 25—DISCONNECTING SWITCHES, 3000-AMPERE, 12,000-VOLT, WITH OPERATING MECHANISM

The smooth porcelain was adopted with the intention of obtaining every advantage possible in the strength of the porcelain unit and making the cleaning of the units easier.

The bus copper adopted was three bars, 4 inches by 1/4 inch, laid flat on the insulator cap. It was decided to mount the bus supports directly on the floors and walls and by the wide spacing of phases dispense with the usual barriers. This arrangement puts the copper into the plane of force in the position of its greatest strength. Tests in the laboratory showed that there is a real danger in using such a spacing of bus supports along the bus that the stresses set up by 25-cycle currents will coincide with the natural period of vibration of the length of copper, thus producing a case of mechanical resonance. On account of the low strength of copper, it is not possible to space the bus supports at the maximum distance considering the short-circuit forces above. The sagging of the copper due to its own weight is a limiting factor in the arrangement adopted.

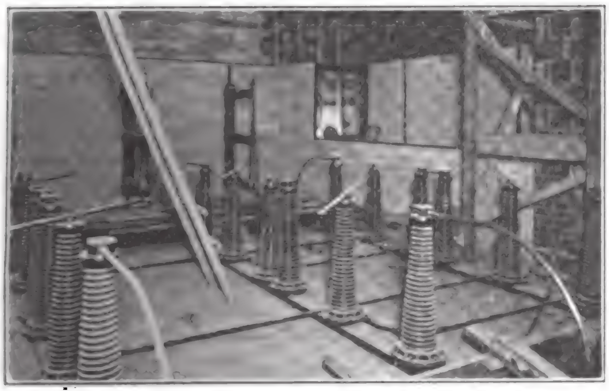


Fig. 26—Disconnecting Switch, 13-Kv., 600-Ampere

Disconnecting switches of 3000-ampere capacity (Fig. 25) are provided on each side of every oil circuit breaker and are located in separate rooms behind the breakers. They are arranged to be operated in sets of three by a hand-operated mechanism with hand wheel outside of the room in which the disconnecting switches are mounted. These mechanisms are locked in the open or closed position by individual Yale locks with master keys for the station. The blades of the switches are locked in the closed position by the operating mechanism.

Pilot lamps mounted beside the hand-operating mechanism indicate the position of the switches and whether the oil circuit breakers are open or closed. This system was chosen in preference to the added complication of a mechanical or electrical interlock between the circuit breakers and the disconnecting switches.

Motor-operated disconnecting switches were considered but it was decided that the advantages would not warrant the extra expense.

Wherever the copper bars are taken through floors and walls, bushings are installed. They consist of a central porcelain tube mounted in a panel of ebony asbestos. The flash-over value is 80,000 volts at 25 cycles. This design gives a very effective and inexpensive bushing.

It is proposed to have all copper bars covered with flame-proof insulation.

110-Kv. Bus and Connections

A continuous current-carrying capacity of 600 amperes was adopted for all high-voltage circuits, which required the use of one-inch diameter, iron pipe size, copper tubing for all 110-kv. connections. As provision is made for ultimately increasing the potential to 135 kv., a standard 42-inch high, corrugated single-piece porcelain post with cemented-on cast iron hardware was installed. These units have a cantilever and torsion strength of 40,000 inch-lb. and have a dry flash-over value at 25 cycles of 350 kv.

600-ampere, 135-kv. disconnecting switches (Fig. 26) of double break, center rotating post, operated by hand mechanism in gangs of three, were adopted, using the same porcelain post as the bus support. These posts, complete with hardware, are interchangeable with the bus supports.

Relay Protection

The simplicity of the main connections in the plant and especially the absence of 12-kv. feeders makes it possible to use differential relay schemes for protection of apparatus and connections. This allows rapid automatic removal of defective equipment from service with a minimum of disturbance to operation. The apparatus and main connections of each unit are divided into the following groups:

Generator,
Main 12-kv. bus,
Auxiliary 12-kv. bus (when installed),
12-kv. connections of transformer,
Transformer bank,
110-kv. connections of transformer,
110-kv. busses.

Each conductor where it leaves the group carries a current transformer These current transformers are so connected to relays that if the current in each phase leaving the group is not equal to the current entering that phase, the relay will carry the difference in the currents, or in other words the current to a fault. If there is no defect inside the groups, current leaving will be equal to current entering and there will be no relay action, no matter how heavy the through current. To insure correctness of operation, the following precautions have been taken:

1. Current transformers are of special design to give correct ratio even with heavy currents.

2. Impedance in secondary wiring has been kept low by short connections. The only equipment connected is the relays which are in the differential circuit and carry fault current only.

3. Current transformers are placed outside the oil

circuit breakers which would isolate any group so that a defective breaker would be cleared on both sides.

All differential relays are of the instantaneous overload plunger type except for transformer differential which are inverse time overload induction type. Generator differential relays have also a hand reset feature to increase the certainty of operation.

Each differential group of relays is arranged with multiple contact relays to trip the necessary circuit breakers to isolate the defective equipment. In case of the generator differential, the field circuit breakers are also tripped.

In addition to the differential relay groups the following relays have been installed (Fig. 16):

1. A relay in the ground connection of each unit to give an alarm in case of ground current. No switches are tripped.

2. A directional relay on each generator, of the three-element induction wattmeter type restrained by a spring. The principal function of this is to check careless synchronizing. It trips out the generator oil breakers.

3 A ground relay on the 12-kv. connections close to the transformer bank on each unit. It protects this section of the wiring including the transformers 12-kv. bushings which are not included in any of the differential groups. This is an inverse time overload induction type relay.

4. A set of inverse time overload relays of the induction type on each outgoing line. This consists of one relay for each phase and one for grounds.

5. A set of inverse time overload relays in the main 12-kv. bus between units to separate them in case the units drop out of step with each other.

An annunciator is provided with each unit which indicates by a drop and an alarm bell which relay was operated.

Several operations of portions of the relay equipments have shown that they function as intended.

All current transformers on the main circuits are of the bushing type, those for 12-kv. circuits having the core and secondary winding mounted on high-grade condenser bushings placed over the three 4-inch by 1/4-inch copper bars. This particular design permits several secondary windings to be mounted on the same bushing.

The 12-kv. potential transformers are of strong construction with an especially high insulation test and are connected through protecting resistors, fuses, and disconnecting switches to the main circuits, the disconnecting switches being in a separate room from the fuses.

Reactors

Reactors are installed only between 12-kv. main bus sections, *i. e.*, between generators. They are of the cast in concrete type with the conductors and the concrete impregnated with varnish. The continuous current-carrying capacity is 2380 amperes with a temperature rise not exceeding 80 deg. cent. above 40 deg. cent. ambient temperature. They will safely carry short-circuit current for 12 seconds. The rating is 12,000 volts, 25 cycles, single-phase 5 per cent reactance based on 2165 amperes, the normal rated current of one 45,000-kv-a. generator. Protective resistors are mounted within the reactor and connected to its terminals.

These reactors are located on the generator floor on elevation 284, below the 12 kv. oil circuit breaker rooms.

Service Apparatus

All services except oil switch control and signal lamps are 25-cycle operated. Power is obtained from two turbine-driven three-phase service generators each rated at 2200 kv-a., 2300 volts, 25 cycles, 500 rev. per min. In addition, power for service is available from a 12-kv. line from the Ontario Power Company.

These service turbines are rated at 2800 h. p. each at 500 rev. per min. under 305 feet head. On these units, the governors, governor pumps, etc., are entirely independent of the main governor system. Oil is used as a medium in these governors, and is supplied by two gear pumps with motors mounted on the same base as the pressure tank.

In general, all motors of 25 h. p. or larger are operated at 2200 volts, whereas smaller three-phase motors are 550 volts.

Generator air exhaust fans, pumps, compressors, shop equipment are electrically operated.

Direct current for operating oil circuit breakers, rheostats and other small motor-driven devices is at 230 volts and is obtained from a 15-kw. motor-generator set. The induction motors are supplied from a 550-volt service feeder. The generator floats on a 230-cell, 154-ampere hour lead storage battery. The generator and battery equipment is in duplicate, so that one generator and battery unit can float on the load at approximately constant voltage while the other battery is being charged. A middle tap is brought from each battery for connection to emergency lighting circuits.

Switchboard indicating and signal lights are supplied from 32-volt d-c. circuits to enable tungsten lamps to be used. Power is obtained from a 4.5-kw., 32-volt generator driven by a d-c. motor from the 230-volt battery, and floating on a 16-cell, 23-ampere-hour lead battery. This unit is in duplicate with one motor-generator and one battery for each 230-volt battery. Better economy is expected from these lamps than from the standard higher-voltage ones.

Arrangement of Service Apparatus. The service electrical circuits are shown in Fig. 27. The principal distributing center called "Section A" is located near the service generators. The two service generators, the incoming feeder from the Ontario Power Company which has been stepped down through a 1500-kv-a., three-phase, 12,000 to 2300-volt transformer, and all service feeders are connected to a main 2300-volt bus

through cell-mounted oil circuit breakers. The generator, incoming feeder and main bus breakers are electrically operated from the main control room. The service feeder breakers are hand-operated. A 2300-volt transfer bus is provided for emergency operation. Power for 550-volt services is obtained from the 2300-volt system through three 300-kv-a. 2300 to 550-volt

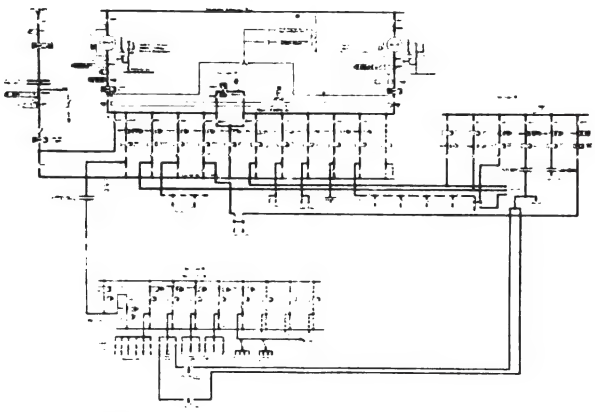


FIG. 27—DIAGRAM OF SERVICE CIRCUITS

transformers to a main and a transfer 550-volt bus. All 550-volt oil circuit breakers are hand-operated and mounted on pipe framework. Section "B" center is located near unit No. 4. It is supplied by two feeders from the 2300-volt bus in Section A. These will eventually be continued to Section C station at the north end of the completed plant, which will be similar to Section A. Section B contains transformers for local services and is a switching center for 2300-volt feeders. The fans and governor pump feeders are arranged as

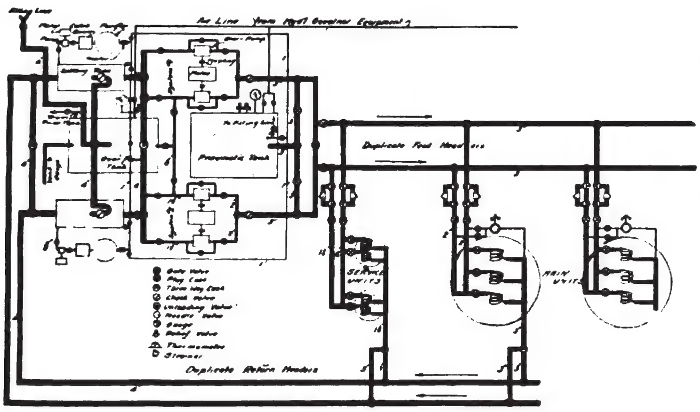


FIG. 28—DIAGRAM OF LUBRICATING OIL SYSTEM

"ring" feeders between Sections A and B so that each has two sources of power. The auxiliary exciter sets are on a ring feeder from Section A to Section C. The generator bearing oil pumps and the governor pressure air compressor have each 550-volt feeders from Sections A and B. The service generators are protected by differential relays and by inverse overload induction-type relays, the latter type being used also for protection of the feeders.

The lubricating oil piping diagram for the main and service generators is shown in Fig. 28. This consists of a central plant of purifying and pumping apparatus with pressure and return headers all in duplicate. Each half of the system is of sufficient capacity for five units. Oil is distributed to the generators by pump pressure and the return oil passes into a settling tank. Any water or sediment settles to the bottom of the tank and passes out to a centrifugal purifier and the purified oil is returned to the system. Each generator requires about ten Imperial gallons per minute of oil. In addition to the duplicate oil pumping equipment, the system is provided with a storage of oil under air pressure suitable for operating the plant for one hour.

The transformer oil system is shown diagrammatically in Fig. 29. Tanks of sufficient capacity to hold all the oil from one bank of transformers are provided and are connected to a "good oil" and a "bad oil" header, which in turn connects with the five banks of transformers. The valves for the storage and purify-

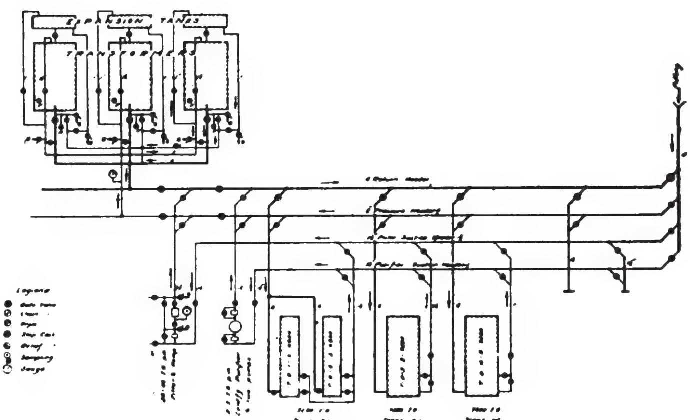


FIG. 29—DIAGRAM OF TRANSFORMER OIL HANDLING SYSTEM

ing equipment are symmetrically arranged and located so that all operations may be performed from one point. The valve arrangement allows the pump and filter press or purifier to be connected with any tank and either header, meanwhile the operator can see at a glance just what connection he is making.

The switch oil apparatus follows the same layout as the transformer oil system, though on a smaller scale. There is no piping connection between the transformer and switch oil systems.

Water for cooling purposes for the transformers and for the generator bearings is obtained from a header connected through valves to the main penstocks, thus eliminating pumping equipment. This header, located in west piping tunnel at elevation 267, is sectionalized by valves between penstocks. Duplicate feeders to each generator and bank of transformers are installed. The house service supply and fire hydrant supply are also obtained from the main header, which also furnishes water through the filters to the turbine bearings.

110-Kv. Outgoing Circuits

The 110-kv. circuit on each unit is brought out of the building through pent houses on the roof by means of compound-filled porcelain bushings. Oxide-film lightning arresters are installed indoors on elevation 375 on each unit.

The single-circuit transmission line for each unit is of 45,000-kv-a. capacity, using steel-cored aluminum cable. The connections of 605,000-cir. mil. cable from bushings to the transmission line are carried on suspension-type insulators, from the tower structure on the roof to special towers on the edge of the roadway at the top of the cliff in front of the screen house, thence to a tower structure on the roof of the screen house, from which the circuits spread out to the standard transmission terminal towers. Two circuits connect to existing transmission lines at Niagara Falls, and additional new circuits under construction extend westwards to connect to more distant existing stations on the 110-kv. system.

Lighting

The lighting of the ultimate plant will be fed from three separate 225-kv-a. banks of 2200/220/110-volt transformers; two banks being installed at present. These banks will feed their respective sections of the building and the distributing boxes are so arranged that in case of failure of any one section, jumpers may be temporarily and quickly installed from adjacent sections. In general, the lighting has been laid out so that all high and low-voltage bus and apparatus, piping, etc., are fully illuminated without undue glare. An automatic transfer switch is installed so that certain circuits may be connected to the 230-volt control battery in case of failure of the a-c. supply.

All feeders from the switchboards are composed of single-conductor rubber-covered double-braided cables. Small wiring from panel boards is of standard rubber-covered double-braided conductor except that in places where excessive moisture is encountered 30 per cent para rubber is used. Rigid galvanized conduit is used throughout and where exposed to moisture shims are used to support the conduit clear of the walls and ceilings.

Telephone Systems

An automatic telephone system is to be installed so that communication may be held between the operators throughout the plant with a code system for emergency conditions. This system will be so designed that it may be connected to the private telephone system of the Commission. Arrangements are being made to install, as a standby for system operation, a wired wireless set.

The engineering and construction work on this development have been carried out under the direction of the commission's staff with Mr. H. G. Acres as chief hydraulic engineer, and Mr. E. T. J. Brandon as chief electrical engineer.

The author wishes to put on record his appreciation of the loyalty and devotion of the entire engineering and construction staffs of the Commission in carrying through the work on this development.

REQUIREMENTS FOR ELECTRICAL MICA

Requirements for mica for electrical purposes relate to dielectric strength, heat resistance and flexibility, states the Bureau of Mines in Serial 2357. All good electrical mica is sufficiently resistant to heat for ordinary electrical equipment and this quality is, therefore, rarely specified. Specifications for dielectric strength vary for different uses and with different consumers for similar uses. Navy Department specifications call for a dielectric strength of not less than 25,000 volts for each 1/64-inch thickness. Mica has such a high dielectric strength that failures most commonly occur in defective spots. It is very important, therefore, in selecting material where high dielectric strength is required that the mica be given a careful visual examination so that all defective sheets may be rejected.

INDUCTIVE INTERFERENCE AND ELECTROLYSIS

A new illustrated publication, Reprint 118, has just been issued by the Westinghouse Electric & Manufacturing Company, embracing an article by Professor Chas. F. Scott on the subject "The Question of Inductive Intereference and Electrolysis as Related to Railroad Electrification."

The publication reviews briefly the causes of inductive interference and the remedial measures which have been applied citing definite experiences with alternating single-phase installations. The conclusions drawn is that power transmission circuits with solidly grounded neutral may be expected to produce telephone disturbances of the same kind and of even greater intensity than those caused by electric railways.

Following this is a chapter devoted to a comparison between a-c. and d-c. railways and covering the subjects (a) noise during normal operation; (b) effect of ground potential under normal load conditions; (c) magnetization of loading coils at a time of short circuit; (d) trolley short-circuit conditions; (e) transmission line conditions and (f) location and character of specific electrifications.

The third chapter deals with the telephone circuit pointing out that the possibilities customarily classified as incidental to interference with the communication system have generally proved only apprehensions. The fourth chapter, on electrolysis, shows that the effects of corrosion by alternating currents under ordinary conditions of practise may be regarded as negligible while with direct-current railways the cost of remedial measures should be included as a part of the cost of the electrification.

Questions Relating to Standards of Rating, with Particular Reference to Large Machines Using Class B Insulation

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FOR the past two years the Standards Committee has been studying the present rules concerning the temperature limits of Class B insulation and the detector method of temperature measurement, as applied to large machines, and related subjects.

The Electric Machinery Committee of the Institute has suggested that an opportunity for general discussion of these questions be given members of the Institute and this meeting devoted to machinery rating and temperature limits is the result.

This paper is intended to bring to the attention of members desiring to contribute to this discussion some of the questions that are before the Standards Committee.

This statement, it should be understood, is unofficial and should be considered only as an individual expression of opinion where any opinion is expressed or preference shown for one proposal over another.

Basic Principle of Rating

The principle employed in the A. I. E. E. Standards for determining the limiting temperature rises as a basis for rating is the so-called hottest-spot principle. The application of this principle in any particular case involves the determination of two quantities or figures; the limiting safe temperature of the insulation employed, and the difference between the hottest-spot temperature and the highest temperature it is possible to measure by the designated commercial method. Both of these figures are difficult to establish and in few, if any, cases can they be established to the satisfaction of everyone. As a matter of fact, agreement on most values of limiting temperature rise in use has been reached by reason of general experience, and current practise, rather than solely by the method set forth in the first chapter of the A. I. E. E. Standards.

There are two methods of approach in arriving at the limiting observable temperature rise: The hottest spot method, that in theory, at least, is scientific in that it is based on the determination of facts; and the direct discussion of temperature rise itself, without the consideration of intermediate steps. This second method is one of negotiation and compromise, and is as far from the usual methods of engineering as are the methods of the "old diplomacy." However, both methods have their advantages and limitations, and probably neither should be used alone. Whichever is considered *the* method, the other should be used to check the reasonableness of the result.

It has been suggested that the "hottest-spot" method or principle, as stated in the A. I. E. E. Standards, should be made less rigid in its application.

It has even been suggested that the complete subject matter relating to this principle be eliminated from Chapter I. A less radical suggestion is that the specific figures or values of conventional allowance and limiting observable temperatures and rises be omitted from Sections 1003, 1006 and 1009. This proposal also contemplates the elimination of specific values of conventional allowance from later chapters of the Rules, publishing only the final result—the limiting temperature rises.

A strong argument in favor of this change is the growing appreciation that it is impossible to establish single values of conventional allowance for all values of limiting temperature (for the various insulation classes) and for the various applications of each method of temperature measurement. If values of conventional allowance are to be retained in Chapter I, it will be necessary to give different values for the temperature limits of Class A insulation and Class B insulation, and to make it clear that the stated values are subject to change in specific applications. Under these conditions, the matter becomes more complicated and confusing, and it is more difficult to establish reasonable values, even for purposes of illustration.

This suggestion of omitting figures from Chapter I would work out somewhat as follows:

Section 1003. The specified differences by which the observable temperatures shall be assumed for purposes of standardization to be lower than the hottest-spot temperatures shall be designated the *conventional allowance.*

The conventional allowance depends on the method of temperature measurement, on the structure of the machine or part, on the limiting temperature rise and on a large number of design factors. Values of conventional allowance can be established only when limited to a specific method of measurement, to recommended applications of that method and to a specific value of limiting observable temperature rise.

Section 1006. This paragraph may be omitted, as it seems unnecessary to devote a separate section to the limiting observable temperatures, since they constitute merely an intermediate step in arriving at the limiting observable temperature *rises.*

Presented at the Annual Convention of the A. I. E. E., Niagara Falls, Ont., June 26-30, 1922.

Section 1009. The limiting observable temperature rises are obtained by subtracting the conventional allowances from the limiting hottest-spot temperatures (to obtain limiting observable temperatures), and by subtracting the standard ambient temperatures of reference from the limiting observable temperatures.

Values of limiting observable temperature rise for specific cases are set forth in later chapters.

It has also been suggested that Chapter I be designated "Introduction" instead of "General Principles," and that the section numbers be omitted. This would emphasize the general nature of this chapter, and still further separate it from the practical or working Rules given in later chapters.

Limiting Temperatures for Class B Insulation

In the present standards, this limit is 125 deg. cent., with the permissive value of 150 deg. cent. as given in Footnote 2, Section 1005:

The Institute recognizes the ability of manufacturers to employ Class B insulation successfully at maximum temperatures of 150 deg. cent., or even higher. However, as sufficient data covering experience over a period of years at such temperatures are at present unavailable the Institute adopts 125 deg. cent. as a conservative limit for this class of insulation, and any increase above this figure should be the subject of special guarantee by the manufacturer.

At its meeting of November 5, 1920, the Rotating Machinery Subcommittee presented to the Standards Committee the following report:

It is the sense of the Subcommittee on Rotating Machinery that the accumulation of data and experience since the present American rules concerning the hottest spot temperature limit of Class B insulation were first adopted warrants it in favorably considering the adoption of a hottest-spot limiting temperature for Class B insulation of approximately 150 deg. to 160 deg., but that a specific recommendation be deferred until investigations now under way and in prospect shall have been completed.

The Standards Committee received this report and circulated it to the members of the Committee for their consideration. At its meeting held January 17th, 1921, the report was accepted and transmitted to the U. S. Committee of the I. E. C. for their information and use abroad. During 1921, the Subcommittee conducted tests (referred to in another paper at this convention) and at the meeting of the Standards Committee, held Feb. 17th, 1922, presented the following definite recommendations, which were forecasted in its preliminary report of Nov. 5, 1920:

The Subcommittee proposes the following temperature limits for large machines with Class B insulation:

Stators: By detectors located between two coil sides:	
Hottest-spot limit	150 deg. cent.
Conventional allowance	20 " "
Total observable temperature	130 " "
Air temperature	40 " "
Limiting temperature rise	90 " "
Rotors: By resistance of the winding:	
Hottest-spot limit	150 deg. cent.
Conventional allowance	10 " "
Total observable temperature	140 " "
Air temperature	40 " "
Limiting temperature rise	100 " "

These recommendations were brought forward at this particular time because of the plans of the I. E. C. to hold a meeting for the discussion of rating in May, 1922.

The Standards Committee adopted its Subcommittee's recommendations, subject to confirmation at its annual May meeting. In response to requests for time for further consideration, the Committee has deferred final action until May 1923.

The recommendations of the Subcommittee for stator temperatures represent a compromise between the lower and higher temperature limits of the present Standards, if observable temperature rises are considered. The present rules provide for a conventional allowance of only 5 deg., while the recommended value is 20 deg. This results in 15 deg. lower value of the rise with the same hottest-spot limit. The limiting temperature rises in the present rules and in accordance with the Subcommittee's recommendation are as follows:

Present Rules:	
With 125 deg. hottest spot limit	80 deg. rise
With 150 deg. hottest spot limit	105 " "
Proposed Rule	90 " "

Separation of Performance Standards From Testing and Operating Instructions

To make the use of the Standards more convenient and to avoid the confusion of fundamentals with less important matter, it has been suggested that the things of first importance—the rules relating to the rating and performance of apparatus—be separated from the less important subject matter relating to testing methods, operation and methods of calculation.

This separation may be accomplished by placing these two kinds of material in different parts of the book or by printing the more important material more prominently.

In this connection, it has been suggested that there be included in each chapter relating to a specific type of machinery or apparatus a concise statement, generally in tabular form, of all values of limiting temperature rise that have been established by the Standards. In connection with rotating machinery, there are a number of sections in the Rules, usually stated as exceptions, that require interpretation before definite values of temperature rise can be arrived at. Table 400 (to be included in Chapter IV) is suggested to cover this proposal in the case of rotating machinery. The addition of this table to Chapter IV makes unnecessary Table 200 in Chapter II.

Other chapters in the present Standards contain similar tables of temperature rises such as, for example, Tables 501 and 502 for railway motors and Table 601 for transformers.

Application of the Embedded Detector Method of Temperature Measurement

The present rules require the use of this method in all machine stators with cores having a width of 50 cm. (20 inches) or over, and in all machines of 5000 volts

TABLE 400—TABLE OF LIMITING OBSERVABLE TEMPERATURE RISES

For machines for operation in locations where the ambient temperature will not exceed 40 deg. cent. for air.

	Designation Number	Items			Method or Methods of Measurement Required	Limiting Observable Temperature Rise Class *O* Insulation	Class *A* Insulation	Class B Insulation
WINDINGS ON STATORS	1	Insulated windings other than 2-3-4	Windings on stators with cores of less than 50 cm. (20 inches) length if voltage is less than 10,000 volts.	Open Type	1	35	50	
					or 2	40	55	
				Enclosed Type	1	40	55	
					or 2	45	60	
			Armature winding on stators with cores of not less than 50 cm. (20 inches) length; also on stators of all machines of 10,000 volts and over.	With two coil sides per slot	3 *a*	No application		
				With only one coil side per slot		No application		
	2	Single layer field windings with exposed surfaces uninsulated and cast copper windings		Open Type	1	45	60	
				Enclosed Type	1	45	60	
	3	Wire field windings		Open Type	1	35	50	
					or 2	40	55	
				Enclosed Type	1	40	55	
					or 2	45	60	
	4	Short-circuited insulated windings			1	45	60	
WINDINGS ON ROTORS	5	Windings in slots such as d-c. armature windings and wound rotors of induction motors		Open Type	1	35	50	
					or 2	40	55	
				Enclosed Type	1	40	55	
					or 2	45	60	
	6	Single-layer field windings with exposed surfaces uninsulated................			1	40	55	
					or 2	45	60	100
	7	Wire field windings..			1	35	50	
					or 2	40	55	
	8	Field windings of turbine type generators................................			2	No application		100
	9	Short-circuited insulated windings......................................			1	45	60	

or more, if rated over 500 kv-a. regardless of core width.

It is proposed to retain the 20-inch core limit, but change the voltage limit to 10,000 volts. The exact wording of this proposal is given under Item 1, Table 400.

The investigations of the Rotating Machinery Subcommittee have shown that the differences between winding temperatures, inside and outside the core and inside and outside the insulation of the embedded portion of the coils, are small in machines of less than 20 inches core length and of less then 10,000 volts, as these machines are ordinarily designed. For these machines, therefore, the thermometer or resistance methods of measurement are adequate.

The opinion exists, in some quarters, that the 20 inch core limit is too low. This results in turbo-generators as small as 500 kw. being equipped with embedded temperature detectors, and experience has shown that, in such small machines, there is little, if any, demand on the part of users, for this method of measurement, either for test or for regular operation. Opinion, abroad, is also in favor of a considerably higher limit in size before this method becomes applicable. If a change were made to 40 inches, the 1500-kw. 3600-rev. per min. turbo-generator would be about the smallest generator in which the detector method would be used.

The purpose of this paper is, as stated in the beginning, to stimulate discussion of the general subject and to invite the opinion of Institute members on the proposals that are referred to. It will be of value and of considerable assistance if a large number of written discussions are brought out. Written discussions sent in after the meeting will also be of service to the Standards Committee (if the author may presume to speak for the Committee) in the consideration of these matters during the coming Institute year.

Tests on General Electric Oil Circuit Breakers at Baltimore

BY J. D. HILLIARD

General Electric Company, Schenectady, N. Y.

DURING the year 1920 an invitation was received by the General Electric Company from the Consolidated Gas Electric Light and Power Company of Baltimore, Maryland and the Pennsylvania Water and Power Company to submit oil circuit breakers for test on their system in Baltimore. The object of the test was to develop a breaker which would satisfactorily handle a short circuit on the 13,200-volt, 25-cycle system as it then existed, and show an apparent factor of safety at that load (20,000 to 25,000 r. m. s. amperes) which would be fairly conclusive to them that the breaker would also handle a short circuit on the system of at least 40,000 amperes. r. m. s. when the generating capacity had been increased by a proposed new generating station.

The tests proposed offered greater advantage than any heretofore made because the power available for testing at this voltage was much greater than any previously employed, because the breakers were to interrupt short circuits at the working busbars of the system, instead of utilizing an isolated bus section as had heretofore usually been the case at tests, and because the tests were to be made by the two companies above mentioned who were to make the report of tests and draw their own conclusions as to operations.

It is obvious that without an exact knowledge of the facts and conditions governing the tests the engineers of power companies might draw wrong conclusions, and if these conclusions were applied to their own system they might be unduly concerned with their equipment, which as a matter of fact might be perfectly safe under their conditions of operation. For that reason it was stipulated that no report of operations were to be made public without the consent of all parties concerned.

It is important to emphasize that the tests on General Electric apparatus herein reported are not to be taken as *applying universally* to all 13,200-volt, 25-cycle *systems and circuit connections* but are conclusive *only upon this particular system under the particular connections used during the tests* with the *special* circuit breakers tested. Conclusions drawn from these tests and applied to systems where different conditions exist and where standard breakers are installed may lead to unfortunate results. It is believed that the wisdom of the company's conservative policy in the rating of current-interrupting apparatus is conclusively proved by these tests.

After it had been decided that the company would accept the invitation and submit breakers for test, consideration was given to the selection of the type of breaker best suited to meet the severe conditions. The Type *F H* breaker was decided upon for the following reasons: Its satisfactory operation in the past; the small quantity of oil these breakers contain relative to their interrupting capacity, with a corresponding small fire risk; the great strength of the oil-vessel; the ease of making inspections and contact repairs on the spot, or of substituting spare vessels and inspecting those removed at leisure; the impossibility of the arc going to ground by burning through the insulating lining of the oil tank; the fact that since each arc is drawn in its own tank there is no possibility of the arcs whipping together causing a sustained short circuit; the possibility of greatly increasing the interrupting capacity of this type of breaker in a cell of the standard floor space and the fact that so many stations were already equipped with this type of breaker.

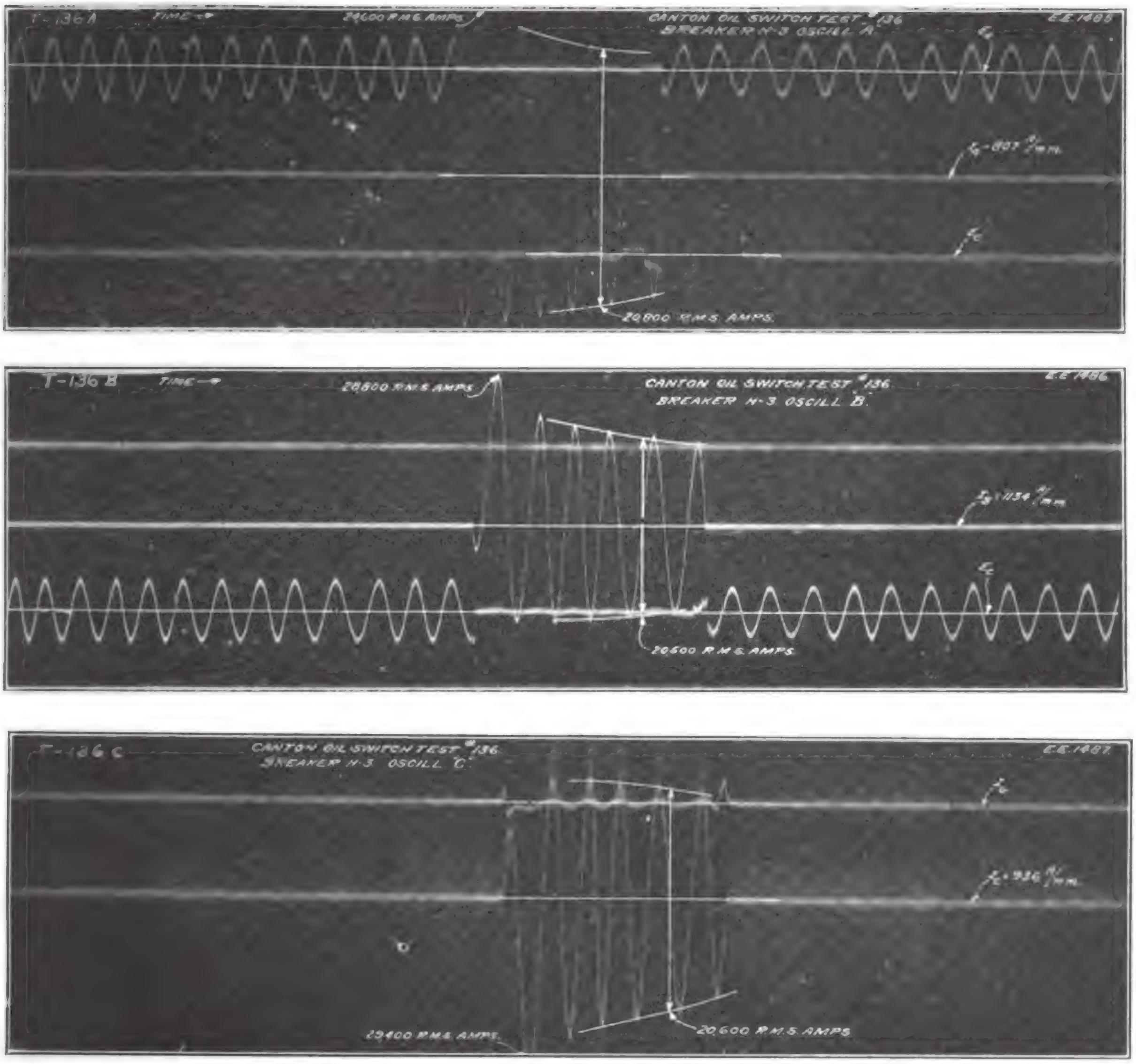
After some preliminary testing the Consolidated Gas, Light and Power Company changes the specifications as to the number of short circuits the breaker was to open, from two to five successive short circuits at two-minute intervals. The tests as reported in this paper, which were to determine the suitability of the breaker to handle five successive short circuits with all the power the operating companies could deliver were not begun until after the changes indicated as a result of the preliminary tests had been made. The remodeled breakers consisted of one *F H*-3 *Y*, one *F H*-6 *Y* and one *F H*-9 *Y*, and a single pole of the experimental *F H D*-17 *Y* the so-called dead pot *F H* breaker. The remodeled type *F H Y* breakers differed from the standard type *F H* breakers in having heavier tops, contact rods, bolts and bolting members, also heavier internal baffle construction, and an external separating chamber of insulating material, leading from the top of each oil tank, through which the gas is ejected and in which chamber any atomized oil vapor is retained by the condensing material contained in the tube, and returned to the oil tank. Various lengths of oil tanks were also provided and tested as well as various separating arrangements in order to determine the one most satisfactory to prevent oil throw.

This external separator was so designed that it could be placed on the present type *F H* breaker in the standard size cells after suitable modifications have been made to the breaker elements.

The Tests

Type *F H*-3 *Y* breaker interrupted an average current of 20,600 r. m. s. amperes once without oil throw.

Presented at the A. I. E. E. Annual Convention, Niagara Falls, Ontario, June 26-30, 1922.



OSCILLOGRAMS NOS. 136-*A*-*B*-*C*

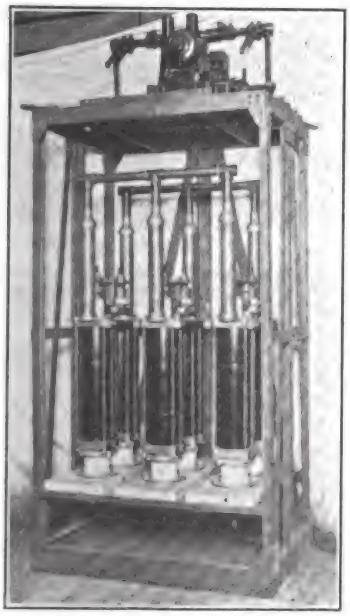


FIG. 1—FRONT VIEW OF TEST BREAKER FRAME WITH TYPE *F H*-3 *Y* TANKS IN PLACE

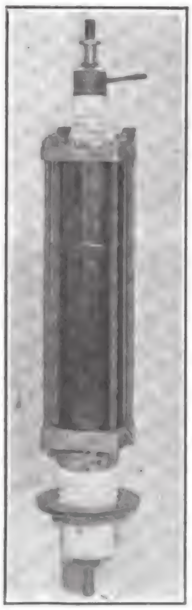


FIG. 2—TYPE *F H*-3 *Y* TANK COMPLETELY ASSEMBLED

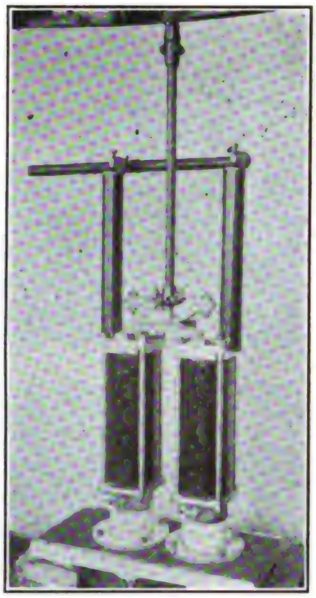
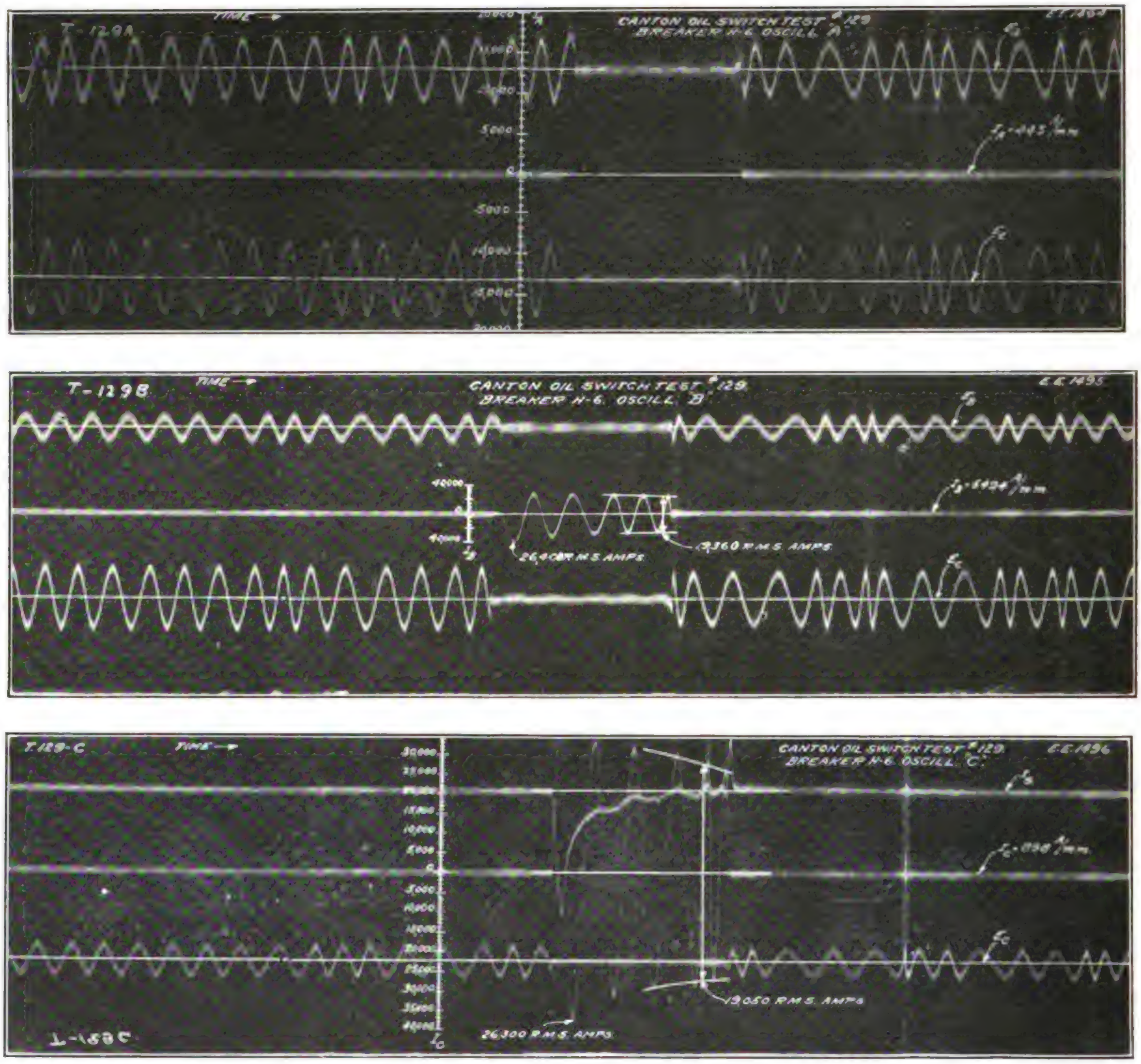


FIG. 3—TYPE *F H*-3 *Y* SINGLE-POLE ELEMENT—15,000-VOLT BREAKER

The same breaker interrupted an average current a second time at 20,200 r.m.s. amperes at the arc without oil throw. At this second shot a defective lever arm on the mechanism broke and the breaker was not tested further. The generator capacity connected was 147,000 kw., oscillograms 136 *A*, *B*, *C* show the circuit phenomena during the interruption. Fig. 1 and Fig. 2 show the triple-pole breaker and a single-pole element as tested, and Fig. 3 shows a standard single-pole element of the breaker as furnished for standard production orders.

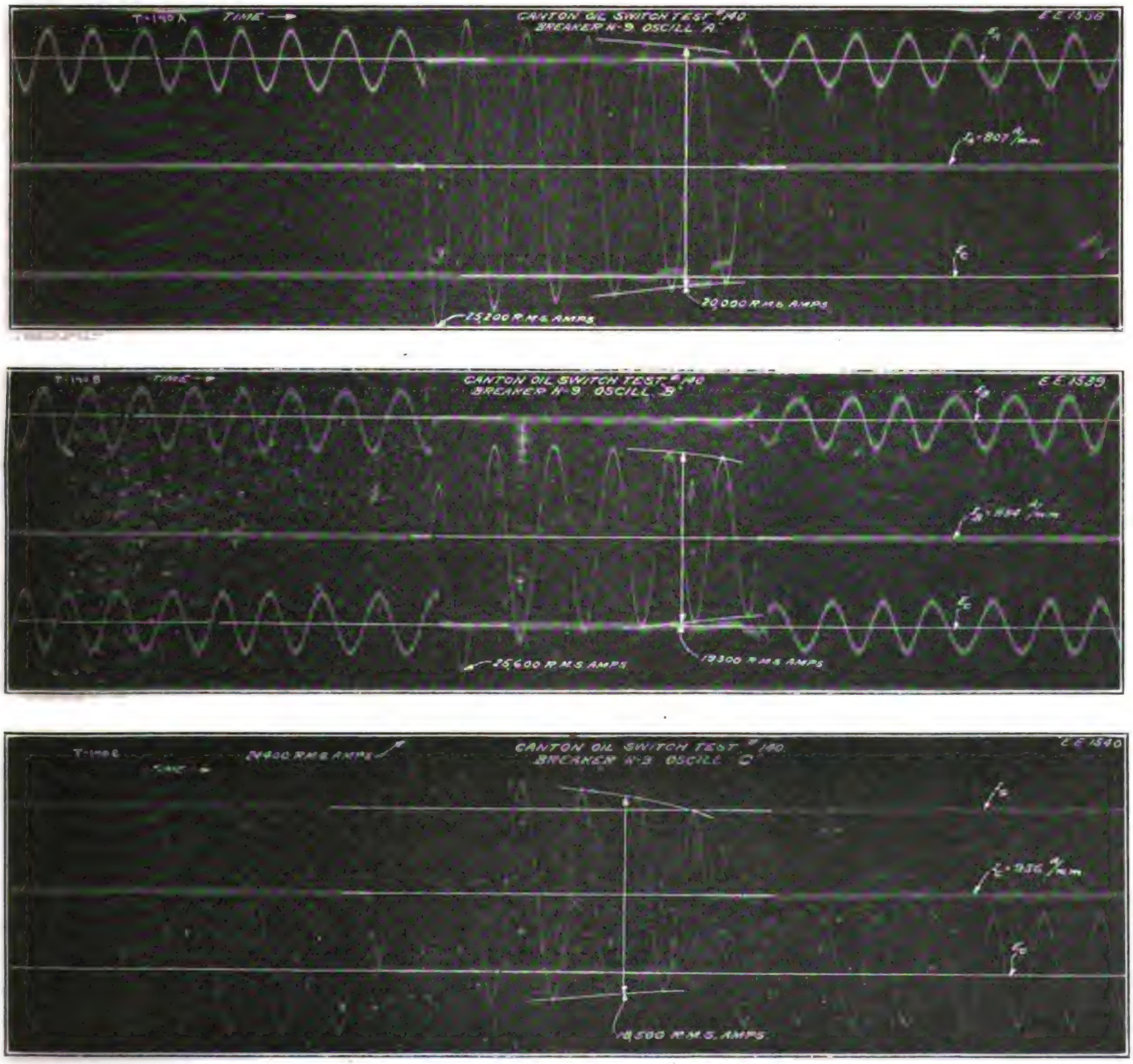
The type *F H*-6 *Y* breaker interrupted five successive short circuits averaging 20,200 r. m. s. arc amperes. A few drops of oil was the extent of the oil throw in any of the tests. Some smoke was emitted from the separating pipes but no distress was shown by the breaker and it was evident that the load interrupted was much below its interrupting capacity. The generator capacity connected was 147,500 kw. oscillograms 129, *A*, *B*, *C* show the circuit phenomena during



OSCILLOGRAMS NOS. 129-*A*-*B*-*C*

Fig. 4—Type *F H*-6 *Y* Oil Circuit Breaker Completely Assembled

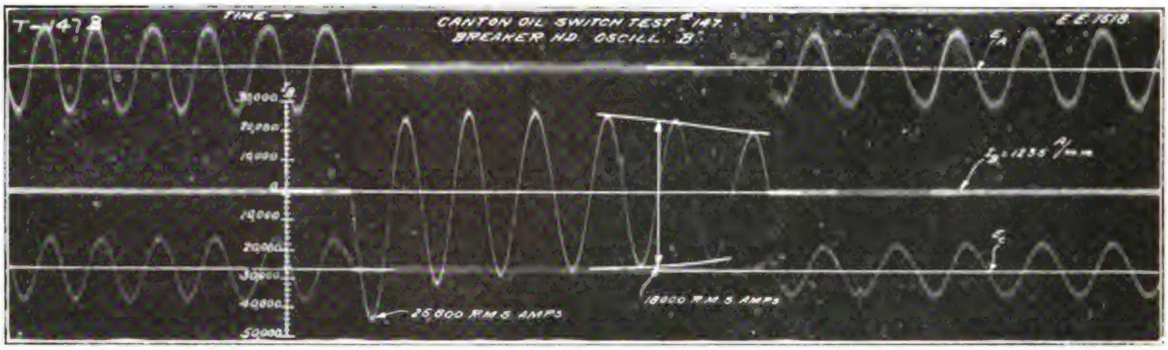
Fig. 5—Type *F H*-6 *Y* Oil Tank Assembled with Bushings and Reenforcing Rods



Oscillograms Nos. 140-*A*-*B*-*C*

the interruption. Fig. 4 and Fig. 5 show the triple-pole breaker and a single pole element as tested.

The type *F H*-9 *Y* breaker interrupted five successive short circuits with an average current of 19,160 r. m. s. arc amperes. The oil throw was limited to a few drops during any test except from a leaky gasket on phase *C*. The breaker evidently has a large reserve interrupting capacity above any load which could be thrown on it during the tests. The generator capacity connected was 147,500 kw. oscillograms 140 *A*, *B*, *C* show the circuit phenomena during the interruption.



OSCILLOGRAM NO. 147

The type *F H D*-17 *Y* breaker—single pole element—interrupted five successive short circuits averaging 17,670 r. m. s. arc amperes. During this series of tests the oil throw was very small and it was evident that the interrupting capacity of the breaker was much greater than the available load which could be thrown upon it from the system. The generator capacity connected was 147,500 kw. Oscillogram 147 shows the phase phenomena during the test. Fig. 6 shows the single-pole element as tested. This test of the type *F H D*-17 *Y* breaker was a single-pole test; the other two poles at the time of the test were the type *F H*-9 *Y* breaker elements.

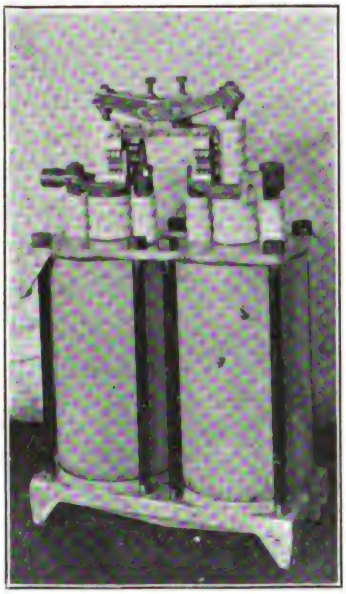


FIG. 6—TYPE *F H D*-17 *Y* OIL CIRCUIT BREAKER, SINGLE-POLE UNIT, 15,000 VOLTS, 1200 AMPERES

This type *F H D*-17 *Y* breaker was not tested with its regular operating mechanism but with the standard type *F H*-9 *Y* mechanism, the single-pole element therefore did not show the exact characteristics it would have shown if its own operating mechanism had been used. The burning of the contacts and contact rods for the five short circuits was small on all of the breakers tested and was substantially the same for all breakers (about ¼ inch was burned from the end of each contact rod.) This is what would be expected because the size of all contact rods was the same.

The quantity of oil lost was negligible and was as to be expected less in the larger oil tanks than in the small tanks. The interrupting property of the oil was not seriously affected by the five interruptions and it is evident that oil deterioration is not the factor which will determine the number of interruptions which can be made by any of these breakers.

The interrupting capacity of any of the *F H Y* type breakers can be increased to almost any desired current by making a small modification of the oil vessels, but the number of interruptions which can be safely made at any current and voltage will, of course, decrease with the increase of current, unless the arcing contacts are increased in size at the same time the current to be interrupted is increased.

The Baltimore tests, as well as other tests where large currents have been interrupted, have demonstrated the necessity of maintaining the arcing contacts in good condition, because the safety of the main contacts are determined by the condition of the arcing contacts. These remarks, apply to oil circuit breakers of any type.

The breaker may be designed for instance to stand four interruptions, but if it has handled two interruptions without examination there are but two left at the guaranteed rating, and at the next case of trouble the breaker may have to open so many times that the main brushes will be seriously burned before the trouble is remedied, and if so, the carrying capacity of the

breaker will be seriously affected. The necessity of keeping the arcing contacts in first class condition at all times on breakers of any type interrupting large currents cannot be overemphasized, the continuous operation of the system and the safety of the breaker both require it.

In the recording by the oscillograph of the currents interrupted, shunts were used instead of current transformers, as the company's engineers feel that they more correctly record the transient phenomena.

In taking the records, two foot films were used as their use enabled us to spread out the wave and thus secure a better record and at the same time assured a record of any delayed phenomena, such as the re-establishment of the arc, should it occur, which could not be had with the short film. With the long film it is also possible to obtain a good record without adjustment of the drive of the oscillograph on breakers having widely different speed characteristics.

Conclusions

The test proved that the *F H* type of breakers could be constructed to interrupt the heaviest short circuit on a large power system within its voltage rating and without oil throw; that the present line of type *F H* breakers could be changed so as to be free from oil throw at their present rating.

We wish to here express our appreciation of the many favors shown us by the power companies during the tests. The manufacturing and operating companies both are deeply indebted to them for supplying the facilities and labor with which to make the tests which made possible the realizing of results not otherwise obtainable at that time. It took a great deal of courage to throw repeated short circuits on the combined systems and the results showed that their belief in their engineering practise and substantial construction were merited, as not a single serious accident to personnel or apparatus occurred during the series of tests.

ILLUMINATION ITEMS

By the Lighting and Illumination Committees

MODERN STREET LIGHTING SYSTEM INSTALLED AT HAMILTON, OHIO

The city of Hamilton, Ohio, has recently installed a modern street lighting system which makes this city at night one of the best lighted cities in that state. The early system, now displaced, consisted of about 750 enclosed carbon arc lamps haphazardly located and mounted at various heights. The illumination received from it was quite low. The new system now in use consists of approximately 1500 incandescent units of the dome refractor, rippled glass globe type, equipped with lamps ranging in size from 2500 lumens (250 c. p.) in the outlying districts up to 10,000 lumens (1,000 c. p.) in the downtown business districts bordering on the White Way. The white-way system (located in the main business district) is lighted with 300-watt, 110-volt, multiple lamps installed in upright encasing units on single light standards spaced 60 feet apart. This part of the lighting system formerly consisted of five-light clusters with four 60-watt and one 100-watt incandescent lamps. The new units are superior both as to effectiveness and economy. A tsome future time this white-way system will be changed from multiple to series. In the downtown districts the 1,000-lumen pendant units are mounted 20 feet high and spaced 300 feet apart. On the wide streets the lamps are mounted on both sides of the street and staggered so as to give the proper distribution of light for both automobile drivers and pedestrians; on narrow streets in this district the lamps are mounted on one side only. In certain locations the height and density of the tree foliage necessitates a mounting height of about 16 feet. In the residential sections of the city 4000- and 6000-lumen (400- and 600- c. p.) lamps are used in pendant fixtures. The units are spaced from 300 to 400 feet apart and are mounted approximately 18 feet above the street. While supplying much better street illumination in every way than the earlier lighting system, the new system requires less power for its operation than the earlier one.

It is interesting to note that the Chief of Police and the Chief of the Fire Department at Hamilton have both declared that the improved lighting has proved itself to be of much assistance to them in connection with their duties.

DEMONSTRATING EFFECT OF VARIATION OF ILLUMINATION

A number of carefully conducted tests has proved that increased production in industrial plants results when high level illumination is employed. This fact must depend on some relation between the ability to see and the intensity of illumination. If a man can see more readily he obviously can work more rapidly, with greater confidence, and increase the output.

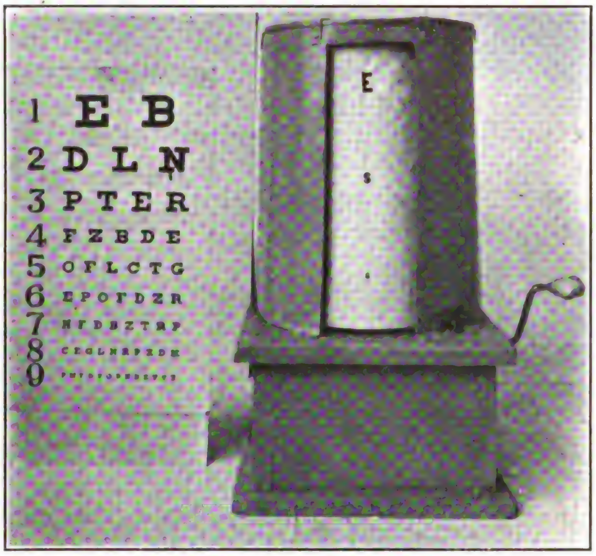
There are two main groups of objects to be observed while working. The first, stationary, and the second moving. One must inspect the work from time to time, observing certain details, and must also watch the object as it moves in the machine.

In connection with demonstrations of industrial lighting which have been conducted throughout the country, two simple devices have proved very useful in convincing the audience that speed of vision is affected by the intensity of illumination. These are illustrated in Fig. 1. In Fig. 1A is shown a typical eye test chart known by the ophthalmologist as the Snellen chart. This is placed on the platform and illuminated to an intensity of two or three foot-candles. One of the audience, at a distance of fifteen or twenty feet, is asked to read as far down the chart as possible. The illumination is then raised to twelve or fifteen foot-candles and the test repeated. Invariably the observer can read one or two additional lines under the higher

illumination. This tends to prove that detail can be observed with greater facility.

The apparatus in Fig. 1B demonstrates the effect of higher intensity on a moving object. A ten inch-phonograph turn table is surmounted by a cylindrical drop on which is placed a series of letters of varying size. Opaque shields limit laterally the visible area of the drop. The turn table is set in operation at a definite speed and the illumination on the apparatus is varied as above. A similar phenomenon is noted. With the high level illumination the letters can be discerned much more readily as they flash past the opening and the smaller type is legible.

An interesting psychological effect is always evidenced. A decided change in apparent speed results.



A Fig. 1 B

The turn table seems to slow down or speed up respectively depending on whether we pass from three foot-candles to fifteen foot-candles or from fifteen to three foot-candles. The governor on the spring motor certainly prevents such a change. In developing this apparatus, the experimental model utilized an electric motor as the driving power. This was connected to the circuit used for illumination and the effect was so marked that one at once assumed that a voltage drop occurred resulting in lower motor speed. Check tests soon indicated that the effect was purely psychological.

By the observation of this device, any one will be convinced that moving objects appear to move more slowly when properly illuminated and can be watched by the operator with less eye-strain.

POOR LIGHTING CAUSES 25 PER CENT OF NIGHT ACCIDENTS ON MASSACHUSETTS HIGHWAYS

Mr. A. W. Devine, headlighting inspector at the Registry of Motor Vehicles, Boston, Mass., who is directly responsible for the enforcement of the motor vehicle lighting laws in the state of Massachusetts recently made an analysis of 800 night accidents which occurred on the Massachusetts highways during 1920 and 1921. A great many more accidents than this occurred during that time, but only 400 representative accidents are analyzed each year; the figures given, therefore, are an average of the results for two years. Mr. Devine found that of the 800 night accidents which he investigated, 25 per cent were due entirely to the lighting conditions; 17½ per cent being due to insufficient road illumination and 7½ per cent to glare.

The ratio of the number of accidents due to each cause is very significant. The popular opinion among state officials and others interested in motor vehicle lighting has been that glare is the predominating evil. The results of this analysis would indicate that as the cause of highway accidents at night, glare is not half so serious as insufficient road illumination.

VALUE OF HIGHER INTENSITIES OF ILLUMINATION

During the past year, Dr. M. Luckiesh of the Nela Research Laboratories has been investigating the effects of higher intensities of illumination on the speed of reading, and has found a definite increase of "speed of vision" as the illumination intensities increased. For ordinary reading matter (black print on white paper) the speed of reading increased 15 per cent when the illumination increased from 4 to 16 foot-candles. For black print on gray paper, the increase in speed was 50 per cent when the illumination intensity increased from 4 to 16 foot-candles. These data show the value of increasing the intensity of illumination and the results can safely be extended to cover many other visual processes in factory, office or home.

Another very interesting and important phase of the investigations was a determination of the illumination intensities voluntarily chosen by a large number of observers. For reading printed matter, such as the Saturday Evening Post, the mean value chosen was about 10 foot-candles (when a maximum of 30 foot-candles was available) and when the paper was dyed gray so that the print was seen on a gray background the mean value chosen was about 17 foot-candles, the other conditions being the same.

Incidentally, it was found that the observers chose more light when the maximum available intensity was large than when it was small. This is best shown as follows:

	Approximate Foot-Candles		
Maximum available intensity	10	30	45
Intensity chosen for ordinary reading	5	12	16
Intensity chosen for reading from gray paper	..	17	..

Reading tests were used because reading is the most extensive visual activity and by using the gray background as well as the white, data were obtained which may be safely interpreted in terms of many other visual activities.

Tests on Westinghouse Oil Circuit Breakers at Baltimore

BY J. B. MacNEILL
Associate, A. I. E. E.
Westinghouse Electric and Manufacturing Company, E. Pittsburgh, Pa.

This paper deals with short-circuit tests made recently at Baltimore on dead tank oil circuit breakers of Westinghouse manufacture. Tests were made against the combined capacities of the Consolidated Gas, Electric Light & Power Company and the Pennsylvania Water & Power Company systems, and currents as high as 24,000 amperes at 13,200 volts were interrupted repeatedly. Tests on breakers of different sizes are described, the rupturing capacity ratings of the breakers referred to, ranging from 10,000 amperes at 15,000 volts up to 40,000 amperes at 15,000 volts.

Improvements of design and construction have greatly increased the ability of this type and make of breaker to handle heavy short-circuit currents and severe duty cycles. The demonstration connected with the opening of heavy short circuits, including oil throwing and gas ejection, has been controlled and the fire hazard greatly reduced. A positive means for preventing oil throw, while at the same time relieving gas pressures in breaker tanks, has been developed.

Data are given regarding tripping speed, length of arc duration, and condition of the oil and circuit-breaker structure after the tests.

THE electrical industry as a whole owes a debt of gratitude to the Consolidated Gas, Electric Light and Power Company and the Pennsylvania Water and Power Company for the broadminded and capable manner with which they have attacked the difficult problem of determining the capacities of heavy power house oil circuit breakers. While considerable testing of a similar nature had been done from time to time in the past, nothing approaching in scope the tests recently completed at Baltimore had been undertaken previously. These operating companies have in this work assumed large expenses and operating risks which could only be compensated for by the far-reaching results achieved.

The time was ripe for such a series of tests. Power concentrations have grown to a point where the capacity and price of switching equipment are serious considerations. Operating requirements also have become more diversified and actual test data under field conditions were needed to meet them. There has grown a strict demand for circuit breakers that will function satisfactorily under maximum operating conditions as the results of inadequate performance become more hazardous with the growth of switching equipment.

The breakers tested by the Westinghouse company were all of the dead tank form (see Figs. 5, 7, 9, 11) this being the general form of oil breaker built by this company for many years. The general features of all these breakers are the same, and the more significant of these are as follows:

All tank structures and mechanism parts are dead and can be solidly grounded.

All contacts, that is the main current-carrying contacts and the arcing tip contacts, are made and broken inside the oil tanks.

The breaker closes against gravity and opens with gravity, accelerated by spring action, both in normal operation and also in event of failure of closing power, failure of mechanical linkage, or failure of latch.

Presented at the Annual Convention of the A. I. E. E., Niagara Falls, Ontario, June 26-30, 1922.

The purpose of this paper is to give the results which are of most general interest with some of the more important details. Briefly, the more marked improvements in this type of breaker, as a result of these tests, consist in:

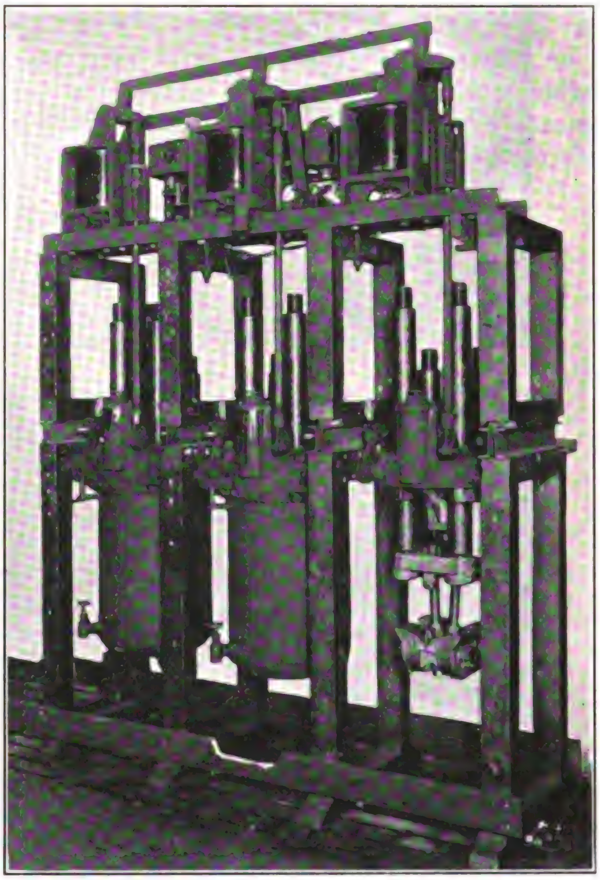


FIG. 1—ELECTRICALLY OPERATED OIL BREAKER SHOWING GENERAL FEATURES OF DEAD TANK BREAKERS
Westinghouse type 0-2, 4000-ampere, 15,000-volt.

(1) Decrease in energy losses within the tanks, with improved control of arcs and gases formed.

(2) Scientific relief of pressures generated combined with reinforcement of mechanical construction where necessary.

(3) Elimination of oil throwing.

The result of these improvements has been increased rupturing capacity and ability to handle more severe duty cycles.

It was realized at the start that a knowledge of pressures developed in the tank structure at the time of rupturing short circuits was necessary. The small pressure gage shown in Fig. 2 was devised so that it could be placed in any location in a tank without interfering with the operation of the breaker as would be the case if the device were large enough to cause grounds or short circuits within the tank. This type of gage consists of a piston *a*, which is free to slide in a cylinder *b*, but the chamber *c* of which is sealed from the surrounding medium. The pressure in the breaker tank, acting on the piston, causes the ball *d* to make an impression on the lead washer *e* and the corresponding pressure can be read from the calibration curve shown in Fig. 3.

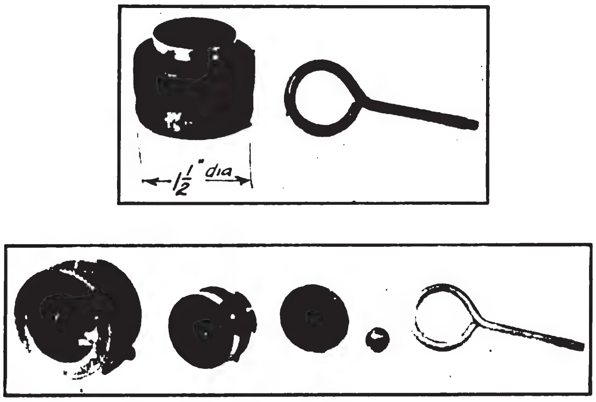


Fig. 2—Pressure Gage
Used in tests on Westinghouse Oil Breakers.

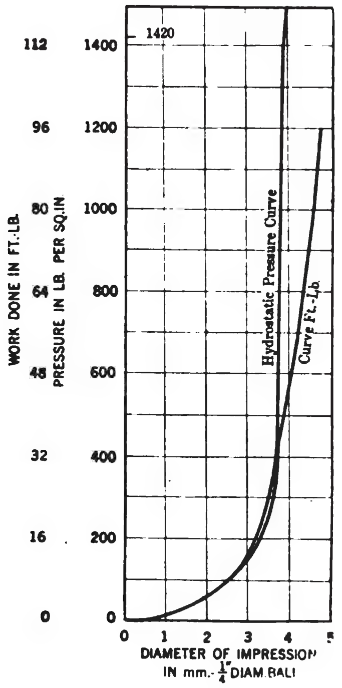


Fig. 3—Calibration Curve of Pressure Indicator

While the results secured from such a device are probably not accurate and have to be used with care, still they are very useful in determining the distribution of pressure over a breaker structure, and in determining relative pressures in breakers of different sizes and different types of design.

Quite early in the series of tests, it was found extremely desirable to provide ventilating and cushioning means for taking care of the pressures generated at the time of opening the circuit. It is realized that a considerable pressure in the tank is necessary to help quench the arc, but the more violent pressures due to gas explosions are not necessary for this purpose, and the ability of a given structure especially on repeated short circuits, can be increased by minimizing such pressures. The oil separator shown in Fig. 4 was developed for this purpose.

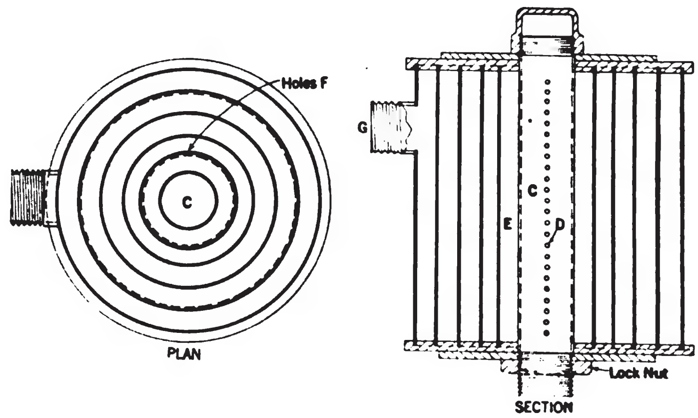
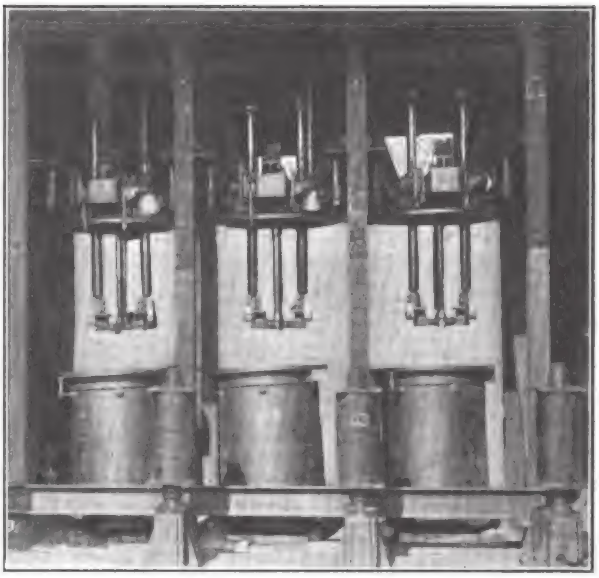


Fig. 4—Oil Separator

The oil separator was designed with the idea of ventilating gas mixtures, relieving pressures due to gas formation, and still preventing the throwing of oil from the structure. This separator consists of several concentric cylinders, the inside one being connected directly to the tank and the outside ones to the atmosphere. The mixtures of oil and gas entering the first chamber from the tank passes at high velocity out of the first chamber *c* through the row of holes *d*, and must then change its direction of flow in order to pass out of the second chamber *e* through the holes *f*, which are 180 degrees away from the holes *d* in the first path. In this way, going from the inner to the outer chamber at constantly decreasing velocity, the oil being acted upon by gravity drops into the bottom of the outer chamber and the gas flows through the vent *g*. With a properly designed oil separator, only a mist of highly vaporized oil escapes on the heaviest short circuits from the breaker structure with the gas, and the rest returns to the tank automatically by gravity as soon as the pressure is relieved.

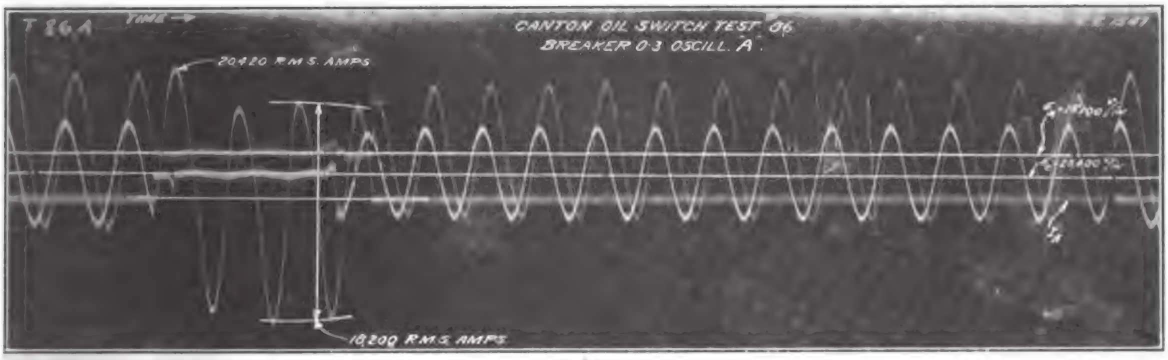
The largest breaker tested was the Type "O-3" shown in Fig. 5. This is a three-pole electrically opera-



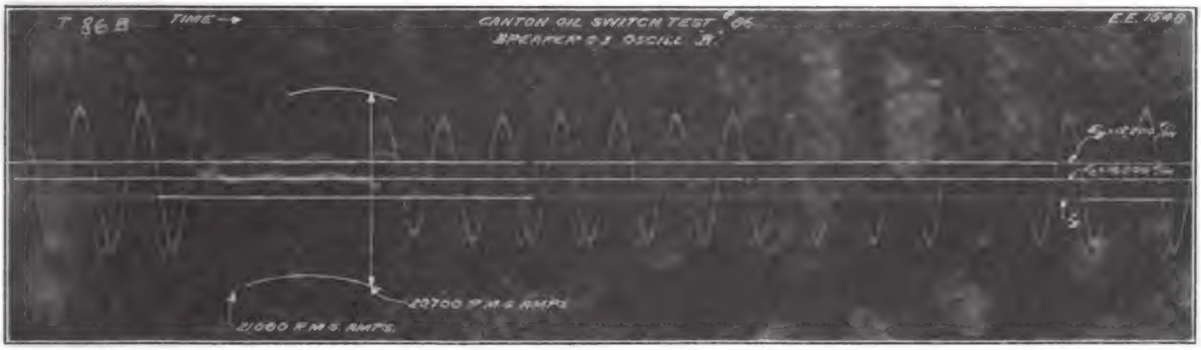
Tanks down—Pole covers removed.

B

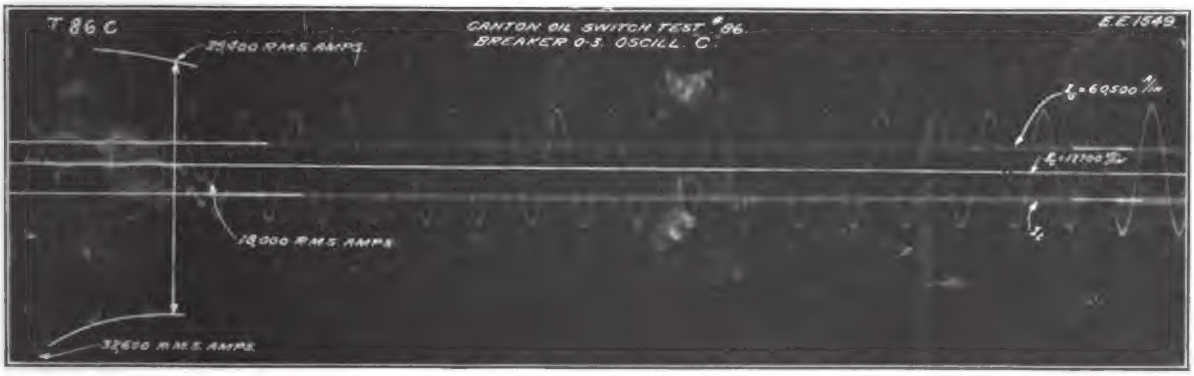
Fig. 5—Westinghouse Type O-3 Oil Breaker
Three-pole, 1200-ampere, 25,000-volt, electrically operated.



A



B



C

Fig. 6—Oscillograms of Short-Circuit Test
Westinghouse type 0-3 oil breaker.

ted round tank breaker with condenser type terminals, parallel path contacts, and noninflammable insulating tank lining. The inside diameter of the tank is 24 inches. This breaker was subjected to eight short circuits on a system set-up calculated at 29,400 initial r. m. s. amperes. The current actually ruptured by the breaker varied all the way from 16,000 r. m. s. amperes to 24,000 r. m. s. amperes. The last seven short circuits were made in succession without inspection of the breaker, and the time elements between short circuits varied from 1½ minutes up to 35 minutes. Probably a small wine glass full of oil was ejected from the three poles during the whole eight tests, mostly in highly atomized form through the mufflers.

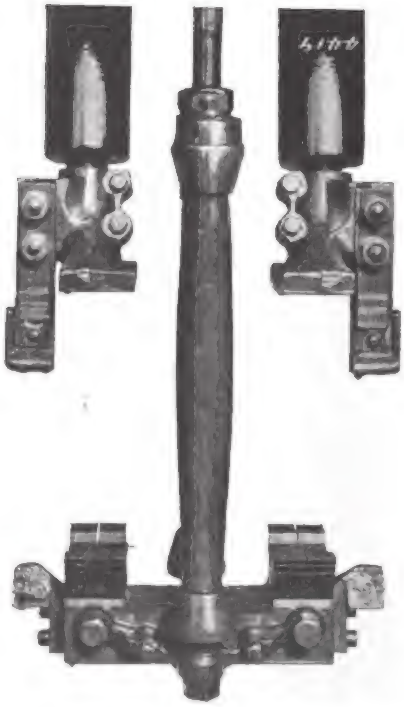
As the rupturing capacity rating of this breaker is 40,000 r. m. s. amperes at 15,000 volts, the pressure generated inside the tanks on these tests was small, amounting momentarily to about 5 per cent of the value of hydrostatic pressure for which the structure is good.

The arcing tips of this breaker opened three cycles after the short circuit was placed on the system, and the arc in all cases was completely ruptured within four cycles from the time the short circuit was placed on the system, the average being 3½ cycles (0.14 sec.). The average time of arcing was 0.5 of a cycle (0.02 sec.) with a maximum of one cycle (0.04 sec.). Samples of the oil used, taken from the three tanks after the completion of the test, broke down when stirred before testing at values varying from 14,000 to 24,000 volts on a 0.15-inch gap. Inspection of the breaker showed that deterioration consisted of burning on the arcing tips, singeing of the tank liners, and some pitting of the corners of the main brush. Later tests will show how pitting of the main contact was reduced. Fig. 6 gives a typical set of three-phase oscillograms showing line current, line voltages and ground current.

The ground current I_g is interesting as at times it rises to considerable values and is due to the arcs in the different phases being extinguished at different times as they reach the zero point of their respective current waves. In order to dispose of a question on which there has been some discussion in years past, we point out that in all these tests we have not found a case where the arc was not ruptured at the zero point of the current wave.

Arranged for test.

A



Contacts after seven short circuits (see text.)

B

Fig. 7—Westinghouse Type *C O*-2 Oil Breaker

Three-pole, 1200-ampere, 25,000-volt, electrically operated.

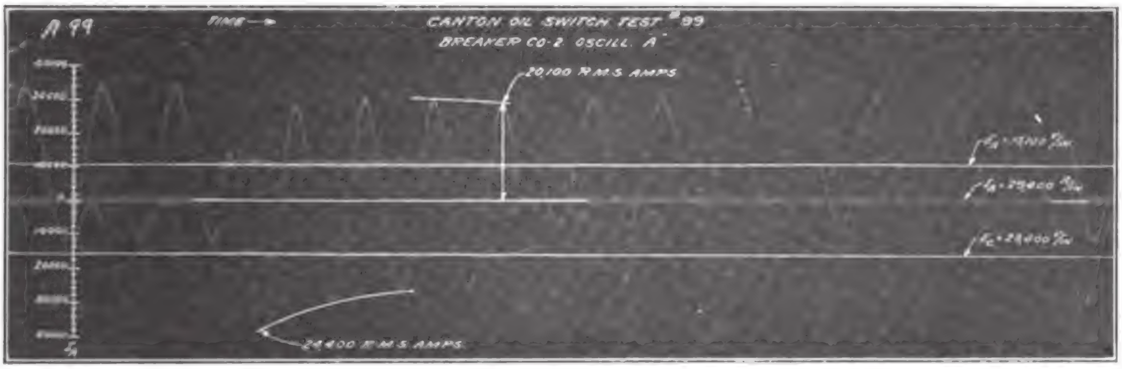
The oscillogram of restored voltage is interesting, showing that the system held up remarkably well considering the size of the short circuit, thus imposing the most severe kind of duty on the breaker for a given current. This was because the short circuit at Canton Substation caused relatively small demagnetization of the machines connected to the system. It is important to note that a large percentage of restored voltage may cause the reestablishment of arcing and consequently more severe duty on the breaker than if the restored voltage is small due to killing of the machine fields.

The type "*C O*-2" breaker shown in Fig. 7 has a cylindrical tank per pole 20 inches in diameter, and the three-pole breaker is built into a compact self-

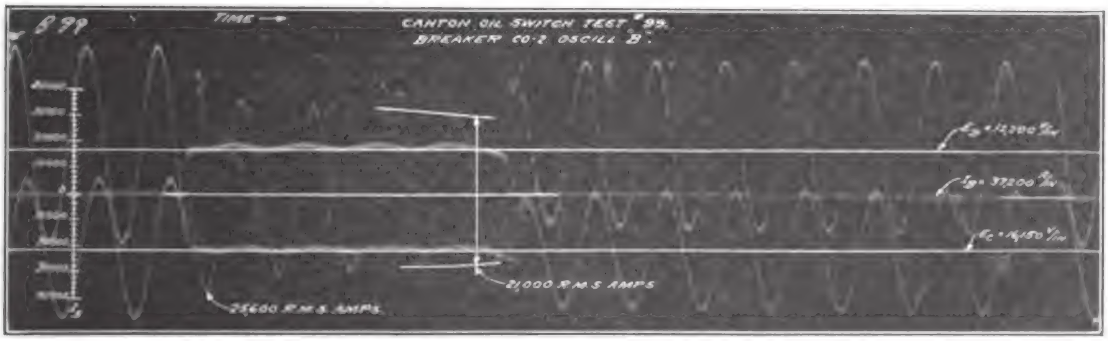
contained unit with tanks, terminals and mechanisms mounted on one steel base. It has parallel path contacts and condenser terminals. This breaker is a modification of the "*C O*-2" breakers now in general use.

This breaker was tested seven times in succession without inspection or alteration on a system set-up calculated at approximately 20,000 r. m. s. amperes. operations in quick succession might have on the structure. The breaker threw probably a half gallon of oil from each tank during the set of seven tests, this oil coming through the oil separators. This particular oil separator was superseded by a superior design shown in Fig. 4, on subsequent breaker tests.

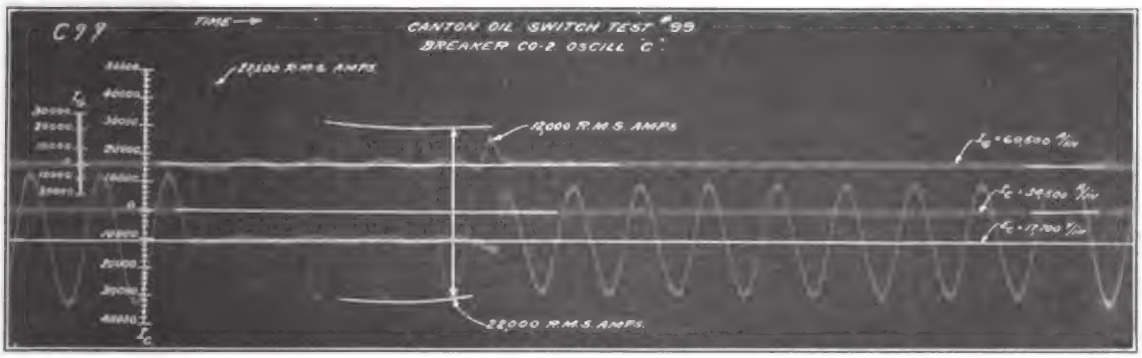
Deterioration of parts was limited to burning of arc-



A



B



C

FIG. 8—OSCILLOGRAMS OF SHORT-CIRCUIT TEST
Westinghouse type *C O*-2 oil breaker.

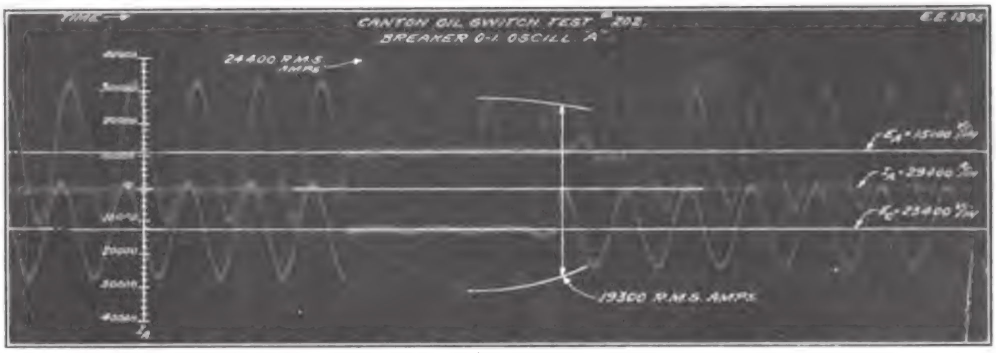
The current actually ruptured varied from 18,000 r. m. s. to 22,000 r. m. s. amperes. The arcing tips opened approximately 3.75 cycles (0.15 sec.) after the short circuit was thrown on, and the circuit was completely ruptured on the average of 4.25 cycles (0.17 sec.) from the time of short circuit. The time of arcing averaged ½ cycle (0.02 sec.).

Five of the seven short circuits were made in a total time of nineteen minutes to determine what effect ing tips, pitting of corners of the main contacts, and a slight scorching of the fireproof insulating tank lining. Samples of oil when stirred broke down at values from 12,000 to 18,000 volts on a 0.15-in. gap. As closely as could be determined, the maximum instantaneous tank pressure was about 12 per cent of the value of hydrostatic pressure for which the structure was good. Fig. 8 shows a typical oscillogram of this series of tests.

The Type "*O*-1" breaker shown in Fig. 9 is a modi-

fication of the line now in general use, and was tested against a system set-up calling for 19,400 r. m. s. amperes, twelve times in succession. The first five short circuits were made in a period of eighteen minutes, and the last four were made in a period of four minutes without waiting for oscillograms. The other short circuits were made at varying intervals. Aside from readjusting a tank gasket after the fifth short circuit, the breaker was not altered during this period of tests. the twelve tests was approximately two quarts which came through the oil separators in highly atomized form. Samples of the oil when stirred broke down from 6000 to 7000 volts on a 0.15-in. gap.

Deterioration of the contact parts was limited to burning of the arcing tips and slight pitting on some corners of the main contacts. There was no scorching of the tank lining. Momentary tank pressures in some cases had run as high as ⅓ of the hydrostatic pressure for which the structure is good. Fig. 10 shows typical oscillograms of this series of tests.



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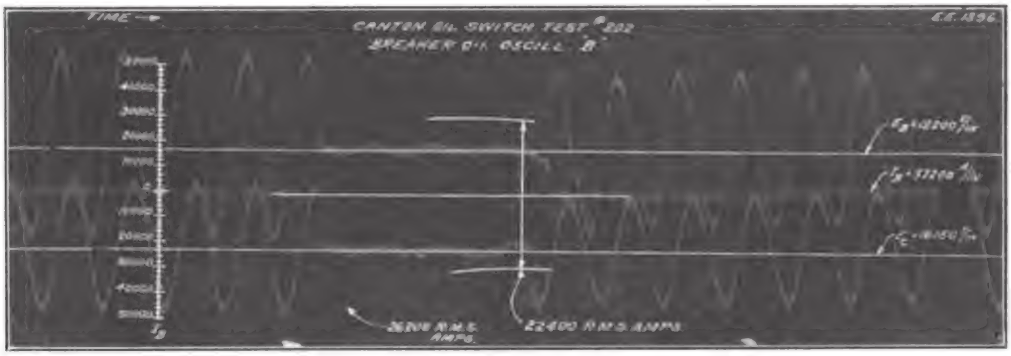

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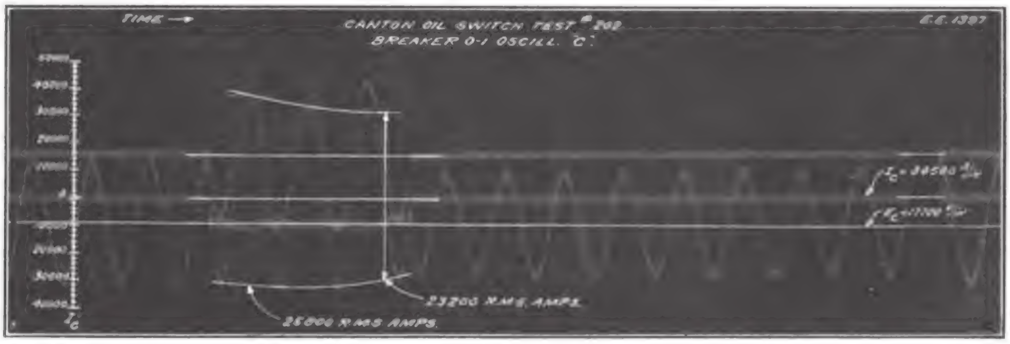


C

FIG. 10—OSCILLOGRAMS OF SHORT-CIRCUIT TEST
Westinghouse type O-1 oil breaker.

The current actually ruptured ranged from 19,000 r. m. s. amperes to 23,900 r. m. s. amperes. The arcing tips parted on an average of approximately 3 cycles (0.12 sec.) from the time of short circuit, and the circuit was completely ruptured on an average of 3.6 cycles (0.144 sec.) from time of short circuit, making an average time of arcing of approximately 0.6 cycle (0.024 sec.).

The total amount of oil thrown from all phases on

The Type "O E-6" breaker shown in Fig. 11 has cylindrical tanks 14½ inches in diameter, and is built in single-phase units with a common mechanism and intermediate cell walls. This breaker was subjected to a final series of nine short circuits against a system set-up calculated at 19,400 r. m. s. amperes. The first five short circuits were made in a period of eighteen

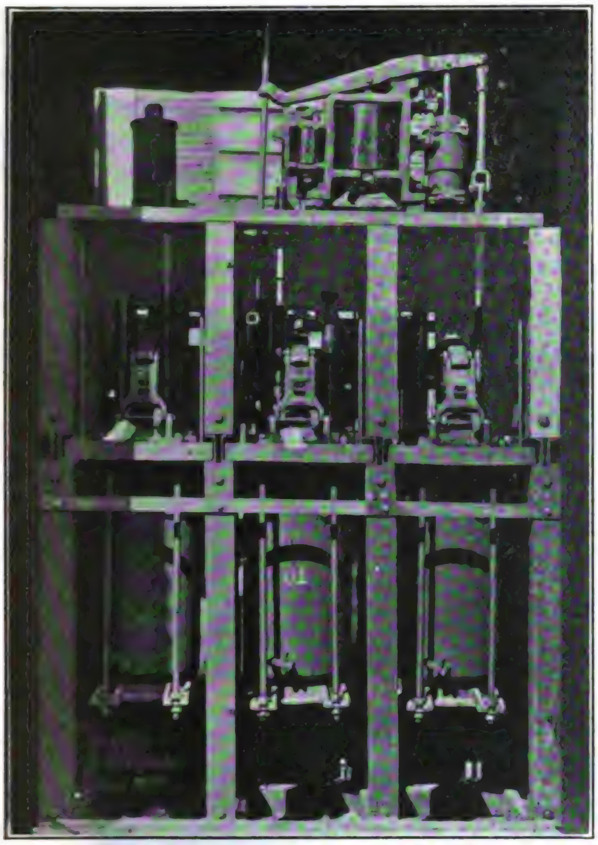


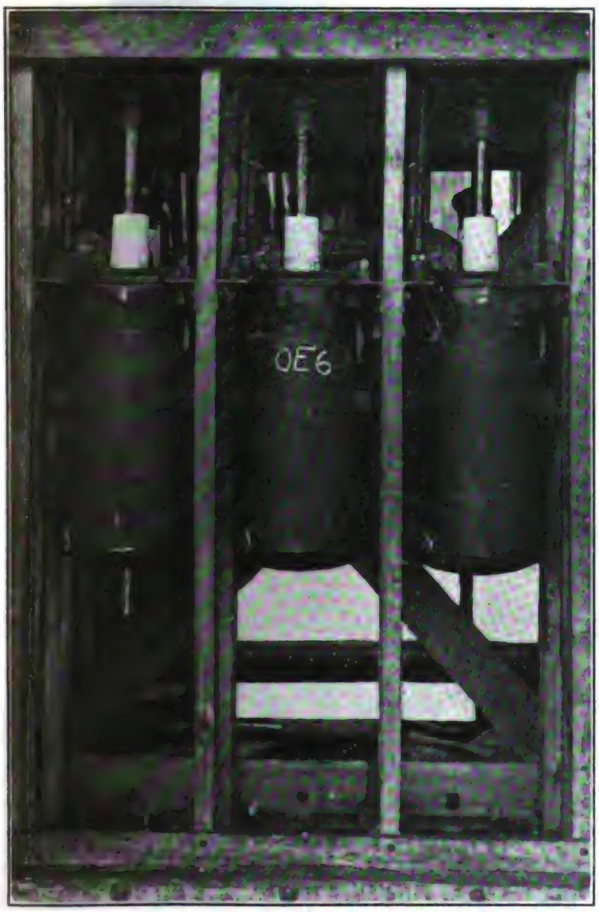
FIG. 9—WESTINGHOUSE TYPE *O*-1 OIL BREAKER
1200-ampere, 25,000-volt, electrically operated.
Arranged for test.

minutes and others at varying intervals. The current actually opened ranged from 16,300 r. m. s. amperes to 21,000 r. m. s. amperes. The average time from the point of short circuit until the arcing tips parted was approximately 3.25 cycles (0.13 sec.), until the circuit was completely ruptured the time averaged 3.75 cycles (0.15 sec.) and the period of arcing averaged 0.5 cycle (0.02 sec.). The amount of oil thrown was practically negligible, being limited to a few drops that leaked through gaskets from time to time, and a slight amount in highly atomized form through the mufflers amounting to half a cup full for the whole series of tests for three vessels.

The oil was extremely black and muddy at the end of the test, and while not tested for breakdown probably was not good when stirred up for more than 25 per cent of its original test value of 35,000 volts on 0.15-in. gap.

The deterioration of contact parts was limited to slight scars on the tank lining, and a rather slight amount of burning on the arcing tips considering the severity of the service. There was absolutely no sign of pitting or burning on the main contact members, as previous test had indicated methods for eliminating this pitting. Fig. 12 shows typical oscillograms of this series of tests.

The modified Type "*E*-6" breaker shown in Fig. 13 is an elliptical tank breaker with the ordinary semi-



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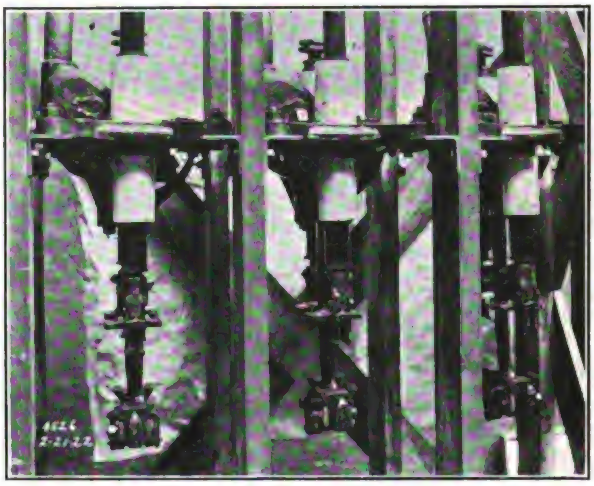


Showing condition after test.
B

Contacts after nine short circuits.
C

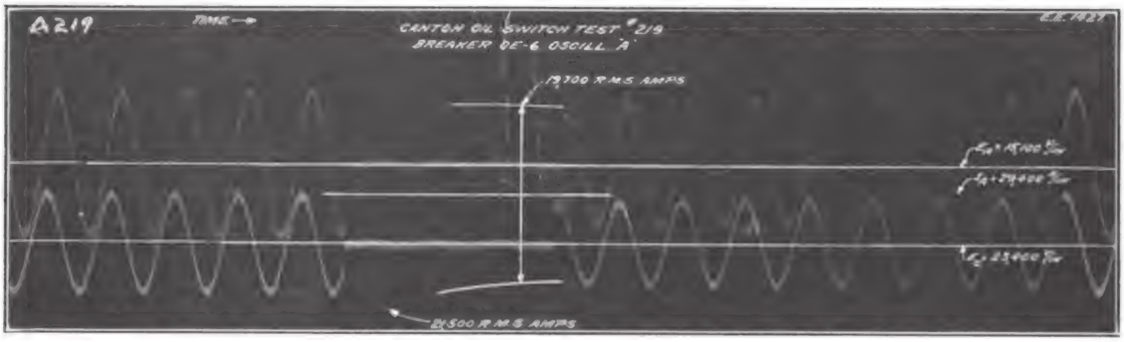
FIG. 11—WESTINGHOUSE TYPE *O E*-6 OIL CIRCUIT BREAKER
Three-pole, 1200-ampere, 15,000-volt, electrically operated.

elliptical form of main contacts and combined porcelain and micarta terminal insulation. It is built in single-phase units operated from a common mechanism, and with intermediate barrier walls. The tests on this breaker are exceedingly interesting, as they indicate the possibility of elliptical tank breakers for heavy power house service where for lack of space, their use may be desirable.

This breaker was subjected to a final test of ten four minutes or an average of less than one minute between short circuits.

Approximately one-half gallon of oil was thrown from each tank through the oil separators on the ten short circuits, this breaker having been equipped with oil separators giving less back pressure in order to relieve the tank pressure. Some little oil leaked out around the tank gaskets.

Depreciation was limited to burning of the arcing



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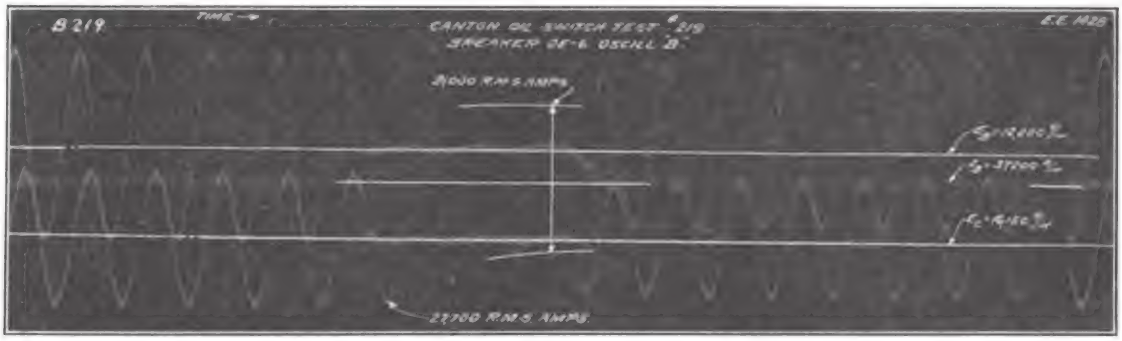

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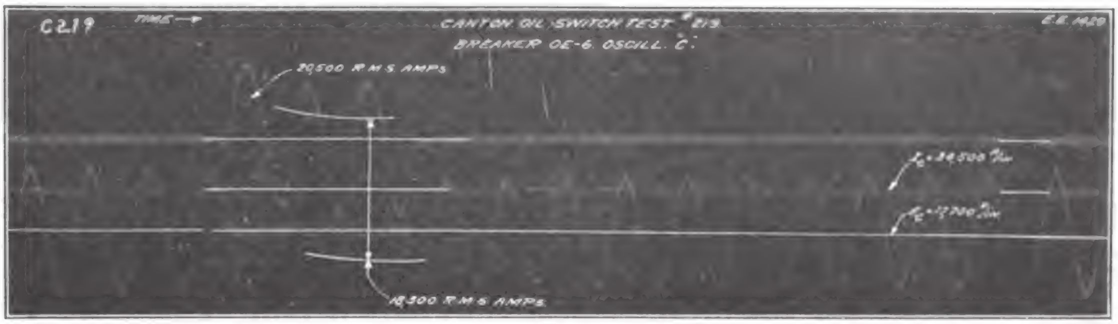


C

Fig. 12—Oscillograms of Short-Circuit Test
Westinghouse type *O E*-6 oil breaker.

short circuits on which the current actually ruptured varied from 10,000 r. m. s. amperes to 11,800 r. m. s. amperes. The average time from moment of short circuit until the arcing tips opened was approximately 3 cycles (0.12 sec.), the average time until circuit was completely ruptured was 3.75 cycles (0.15 sec.) and the average time of arcing was 0.75 cycle (0.03 sec.). The last five short circuits were made in a period of contacts, slight pitting of the main contacts, and slight charring of the tank liners. Fig. 14 shows typical oscillograms of these tests.

The results of the tests detailed above increase greatly our knowledge of the action of higher-power moderate-voltage circuit breakers of this make and type. We can not hastily draw conclusions regarding the action of breakers having different constructions

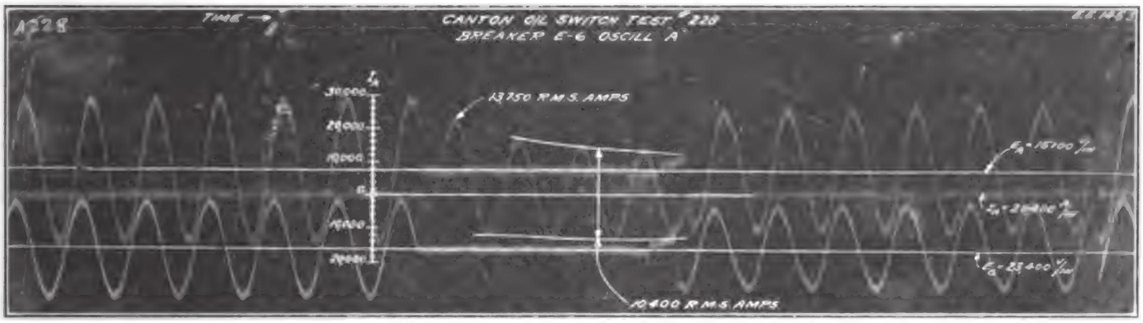
and operating under different conditions from those actually tested. However, it seems these tests have been comprehensive enough to warrant drawing some conclusions.

It seems desirable from the point of view of securing maximum rupturing capacity in a given space that heavy power house breakers be equipped with means for freely venting large amounts of gases without at the same time throwing oil.

It is evident that designs can be produced which will be capable of opening heavy short circuits several times in succession with intervals either short or long between succeeding openings. In other words, the life of the breaker between periods of inspection and repair is principally a function of the amount of copper in the arcing tips.

With proper design, the condition of the oil does not seem as important as heretofore had been thought. This applies only to moderate voltage, heavy capacity breakers, such as those tested, and we wish to emphasize that regular inspection and good maintenance of oil is a desirable thing in connection with circuit breakers in general.

It seems that designs can be made in which the distress on the breaker on repeated short circuits is no greater than that on the first or second short circuit. This, of course, requires a construction which does not depreciate in any way with succeeding short circuits, outside of the depreciation of contact details and oil.



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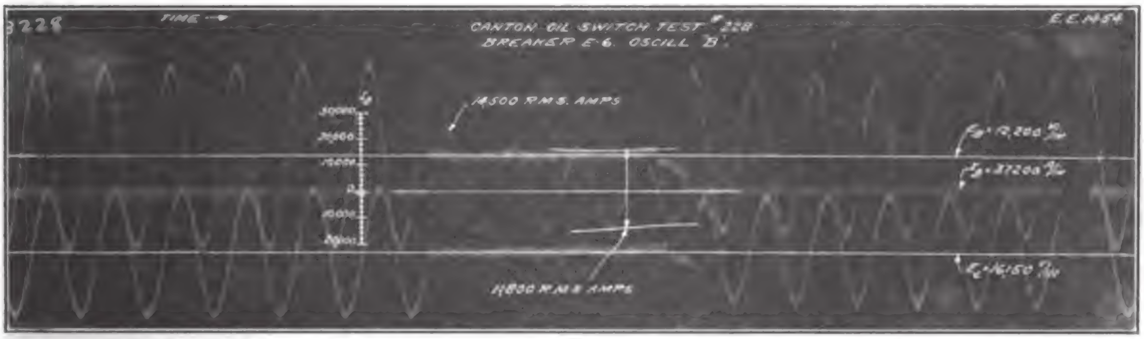

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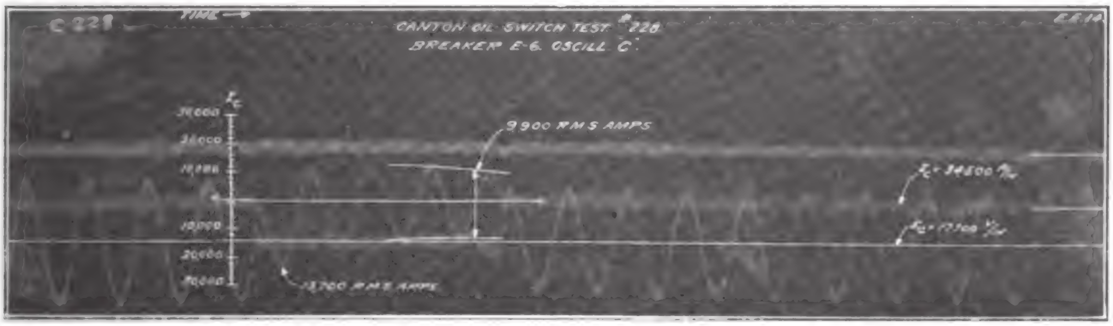

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FIG. 14—OSCILLOGRAMS OF SHORT-CIRCUIT TEST
Westinghouse type *E*-6 (modified) oil breaker.

All the tests detailed above were made on 25-cycle circuits, and it seems probable that the rupturing capacity of a given breaker on 60 cycles is more than it would be on 25 cycles. The data show that on 25 cycles with heavy currents of the order of 15,000 to 20,000 amperes, the arc can be expected to go out in less than one cycle after the arcing tips part. On 60 cycles, the energy liberated in the tanks per half cycle is only two-fifths as much as on 25 cycles, and the opportunity for putting out the arc occurs more frequently on 60 cycles.

Circuit breakers can be made in which the oil content presents practically no fire hazard beyond that found in an oil-immersed transformer or feeder regulator.

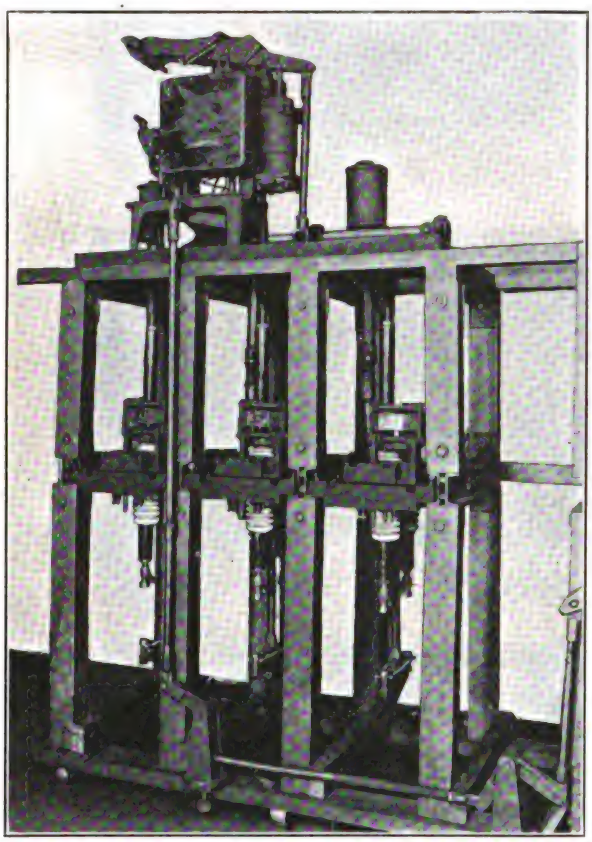

Fig. 13—Modified Type *E*-6 Breaker
Showing application of "oil separators."

It is well to call attention to the fact that sustained circuit voltage and high reestablished voltage are necessary to secure the maximum tests on a given breaker with a given service voltage. A truer criterion of the capacity of the breaker is the product of the current it opens and the voltage at the instant the contacts part. The severity of service also depends in many cases on the value of reestablished voltage. Very misleading results are likely to be obtained where these items are not taken into consideration.

In connection with the above test results it is desired to emphasize the effective and speedy arc rupture in all cases and the control of oil and gas throw by means of positive separating devices.

INTERNATIONAL UNION OF SCIENTIFIC RADIO TELEGRAPHY

The International-Union of Scientific Radio Telegraphy was organized two years ago for the purpose of furthering, through international cooperation, the systematic study of fundamental problems of radio communication. Separate sections have been formed for a number of different countries, and the work of the American section has been in progress for over a year. Recently, systematic measurements have been made at receiving stations in the United States of the intensity of signals received from several French stations and by a continuance of these measurements it is expected that more comprehensive knowledge will be obtained of the phenomena of radio transmission.

A meeting of the American section was held very recently at which the various committees reported, including committees on the study of radio wave intensity, atmospheric disturbances, variations of radio wave direction, measurements of radiations which cause interference, and electron tubes. Particularly in the case of the measurements of the intensity of radio waves, it is important that international cooperation be promoted, since it is only by frequent simultaneous measurements made cooperatively by widely separated sending and receiving stations that accurate results may be obtained.

RADIO DIRECTION FINDERS FOR MARINE USE

On Friday, May 12, 1922, nine companies interested in the manufacture of radio direction finders met at the Bureau of Standards to confer with the Assistant Secretary of Commerce, the Bureau of Lighthouses, and the Bureau of Standards, regarding the production, cost, installation, calibration, and maintenance of radio direction finders on shipboard.

It was announced that the Department of Commerce has decided to install the following radio beacon stations: Boston, Nantucket, Cape Charles, Columbia River, Puget Sound, and, if funds are still available, Delaware Bay, Los Angeles, and Blunt's Reef. These are in addition to the two new radio beacons at Diamond Shoal (off Cape Hatteras) and San Francisco Light Vessel. Three other radio beacons have been in operation in the vicinity of New York Harbor for over a year at Ambrose, Fire Island and Sea Girt.

As a result of the conference, arrangements will be made through the Bureau of Lighthouses, between the manufacturers of radio direction finders and the operators of steamships for the trial and demonstration of radio direction finding equipment produced by the several manufacturers under conditions of practise.

Recent Conclusions Pertaining to Electrical Precipitation

BY WALTER A. SCHMIDT

Western Precipitation Company, Los Angeles, California

Investigations into the phenomena of electrical precipitation of suspended particles from gases during recent years have resulted in some important conclusions. The purpose of this paper is to present these conclusions briefly, without entering into a detailed discussion of the actual equations used in designing precipitators, and of calculations embodying their use.

DURING the past few years considerable progress has been made in establishing an understanding of the relationship between the various factors entering into the phenomena of electrical precipitation of suspended particles from gases, and it is the purpose of this paper to set forth briefly some of the more important conclusions.

In the commercial application of the electrical precipitation process, as practised during the past ten years, many puzzling phenomena were encountered for which satisfactory explanations were entirely lacking. In fact, some of these phenomena appeared to be anomalies. As an example of such an apparent anomaly, we may take the relationship between precipitation efficiency and current flow. It had been early recognized that percentage of precipitation increased as the voltage approached the arcing point, and that the electrical discharge or current flow increased simultaneously and in a more or less definitely related manner. An apparent plausible conclusion was that precipitation efficiency was directly dependent upon current flow, and a review of the early work shows that much time and effort were expended in attempting to increase the corona discharge in certain commercial plants where precipitation results were lower than had been anticipated. Later, certain commercial problems were encountered where the very poorest results were obtained with the highest current flow, that is, with the most intense corona discharge. In fact, in one installation where the problem consisted of collecting thoroughly dry colemanite dust, at a California borax plant, the current could apparently be raised indefinitely without bringing about any appreciable precipitation results. The capacity of the electrical equipment at that plant was limited to 10 kw., but this total energy could be dissipated with ease in a 40-pipe precipitator without effecting any useful results.

For the purpose of this paper it will be unnecessary to enter into a discussion of the theory and practise of electrical precipitation, as these subjects have been thoroughly covered in published articles. For those who are not familiar with the subject, a selected bibliography is appended. Furthermore, R. B. Rathbun and G. H. Horne are presenting papers at this same meeting of the A. I. E. E., which review the subject briefly. For the purpose of this discussion, it is sufficient to say that electrical precipitation is accomplished by passing the fume-laden gas through a unidirectional electrostatic field in which a corona discharge is maintained. In practise, a precipitator consists of a multiplicity of opposing electrode units, one group being of such configuration as to facilitate corona discharge, the other group being of such form as to minimize or prevent discharge therefrom. The former are usually referred to as discharge electrodes, the latter as collecting electrodes. Discharge electrodes may consist of wires, chains, edged strips, serrated edges, or any

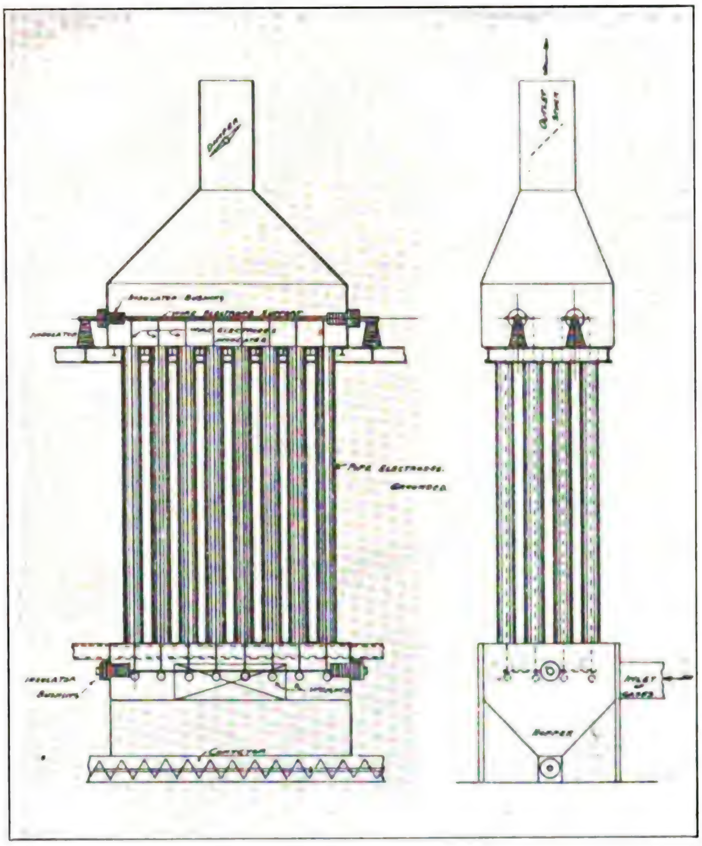

FIG. 1—SCHEMATIC DRAWING OF A PIPE TREATER

other form of conductor that will establish a sufficiently high potential gradient at or near its surface to cause corona discharge. Collecting electrodes may consist of plates, pipes, screens, closely grouped wires, or any other form or arrangement of conductors that will establish low field concentration and thus minimize or prevent corona discharge therefrom. Usually the collecting electrode system is of much greater weight than the discharge electrode system, and consequently is electrically grounded. The discharge electrode

To be presented at the Pacific Coast Convention of the A. I. E. E., Vancouver, B. C., August 8-11, 1922.

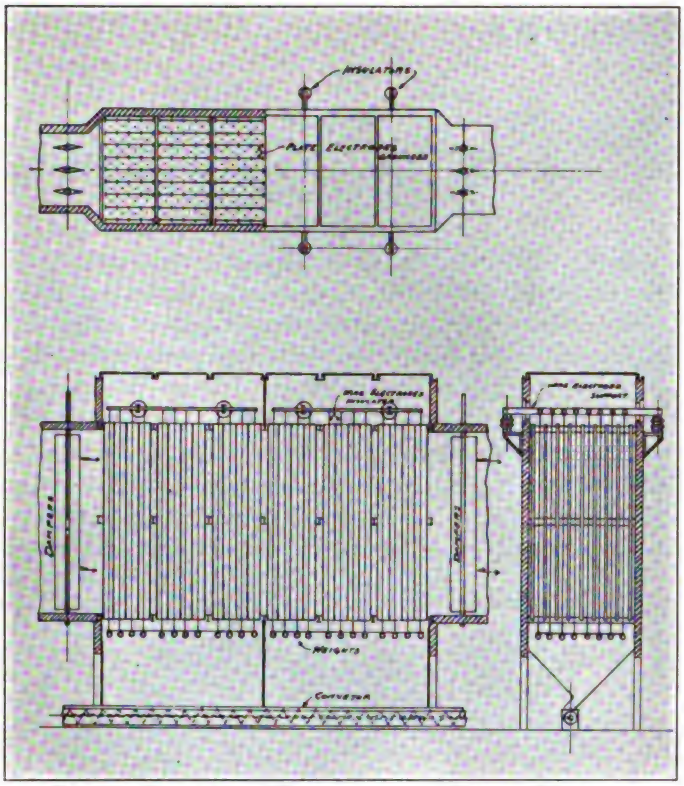

Fig. 2—Schematic Drawing of a Plate Treater

system is mounted upon insulators and is usually charged negatively with respect to ground. The potential difference maintained between electrodes depends upon the electrode spacing and other circumstances, and ranges in different installations from 20,000 volts to 100,000 volts. Unidirectional current is supplied by rectifying high-tension alternating current. The precipitator has been given the name of treater, and the type of collecting electrodes designates the type of treater, as, for example, pipe treater, plate treater, screen treater, etc. The principle of precipitation is in each case the same, the choice of treater depending on circumstances dictated by engineering considerations. Fig. 1 is a schematic drawing of a pipe treater; Fig. 2 is a similar schematic drawing of a plate treater; Fig. 3 is an illustration of a pipe treater installation; Fig. 4 gives a view of a plate treater; Fig. 5 shows a typical electrical control room, and Fig. 6 a typical wiring diagram.

Fig. 3—Pipe Treater Installation.

Fig. 4—View into a Plate Treater

Fig. 5—Typical Electrical Control Room

As already stated, it is sufficient for the purpose of this discussion, to consider that the fume-laden gas is passed through a unidirectional electrostatic field in

which a corona discharge is maintained. However, it must be emphasized that this unidirectional discharge should emanate only from the discharge electrode and travel to the collecting electrode. We shall see that when this condition, which we can call normal, is disturbed, control of precipitation is lost and severe practical difficulties result.

For simplicity we can limit our immediate discussion to a small section of a pipe treater, that is, a short length of pipe, electrically grounded with a negatively charged wire placed along the axis of the pipe. When the voltage is raised above the critical potential, a corona discharge is established, the gas immediately around the wire becomes ionized, and the resultant ions travel either to the collecting electrode or to the discharge electrode, depending on whether they are negative or positive. However, those negative ions which once leave the zone of ionization, travel toward

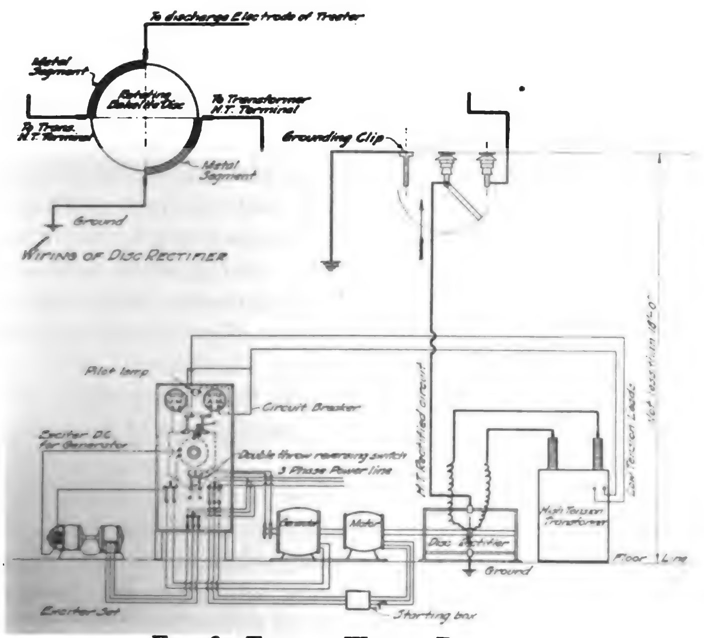

Fig. 6—Typical Wiring Diagram

the collecting electrode and give up their charge to this grounded electrode. Should the gas in the tube carry suspended liquid or solid particles, such particles as come within the zone of ionization may become either negatively or positively charged and thus be either repelled from or drawn to the discharge electrode, while those particles which remain outside of the zone of ionization, become negatively charged and are forced over to the collecting electrode. In practise it is found that a certain amount of the precipitated material is always collected upon the discharge electrode, but by far the greater part of the precipitate is always collected on the grounded collecting electrode.

However, as soon as material commences to collect upon the electrodes, conditions in the precipitator change. To revert to our short tube: It was stated that the ions traveling to the collecting electrode must give up their charge to this grounded electrode. If this were not accomplished, a banked charge would result and discharge would cease. The same is true with charged particles of mist, dust or fume, when they are deposited upon the electrodes. If they do not give up their charge, one of two things must result; either the material will build up a continuous impervious dielectric and accumulate an electric charge upon its surface until discharge ceases, or the material will build up as a porous or discontinuous dielectric, which also will accumulate a charge upon its surface, but with quite different results. As this is a type of deposit which frequently must be dealt with in practise, it deserves special consideration and we will return to it in a moment. The continuous impervious dielectric is rarely, if ever, encountered in practise, and the fully conducting deposit which readily gives up its charge is only infrequently encountered, except in the case of mist precipitation, as for example, sulfuric acid mist. The usual deposit obtained when precipitating dust or fume, is but poorly conducting, due, in part, to poor conductive properties of the material, and, in part, to the poor contact between the precipitated particles themselves. As this is a common type of deposit, and as the handling thereof has presented many serious difficulties, we will be justified in discussing at some length its properties as well as its effects.

E. R. Wolcott has shown (*Physical Review*, N. S., Vol. XII, No. 4, October, 1918) that when a discontinuous dielectric covers an electrode, it acts in all respects as though the electrode had sharp projections at the points of discontinuity of the dielectric; that is, it establishes a point discharge. In other words, it establishes a discharge at the point of discontinuity, of a nature similar to the discharge that would result if the dielectric were replaced by projecting conducting points. It follows that such discontinuous dielectric, when placed upon an electrode, causes a lowering of the arcing voltage. A porous non-conducting deposit acts very similarly and apparently for the following reasons. Such a deposit consists of minute particles separated by equally minute gas spaces. As the solid particles and the gas will have different dielectric properties the electric field will be concentrated at the points of contact or approximate contact of the solid particles. As the charge accumulated at the surface of the deposit increases, and the field through the deposit increases, these points of local field concentration will rise to a field intensity sufficient to cause ionization of the gas within the interstices in the deposit. Once this condition is established, the deposit becomes an ionizer or source of discharge, with most disastrous results so far as precipitation is concerned. In the first place, the gas immediately adjacent to the deposit becomes ionized and this results in a decrease in the dielectric strength of the gas between the electrodes and causes a lowering of the arcing voltage, as Wolcott has shown. Secondly, the deposit being an ionizer, causes an increase

in discharge with consequent increase in power consumption. Thirdly, and most important, both electrodes become sources of discharge, and although instruments placed in the electric circuit will indicate a unidirectional current flow, still we will have two opposing discharges of opposite sign, one emanating from each of the two opposing electrodes. Any dust or fume particle placed between these two discharges will be buffeted back and forth, but may fail to be precipitated on the electrodes. In other words, such a deposit will cause three undesirable results, namely, lowering of the arcing voltage, useless dissipation of energy, and interference with normal precipitation. The following results obtained at a lead smelter, illustrate the effects resulting from the formation of such a deposit:

Condition of Deposit	Power Consumption	Precipitation Voltage	Precipitation Efficiency
Non-conducting.......	7.2 K. W.	52,000 volts	74 per cent
Conducting...........	5.0 K. W.	70,000 volts	97 per cent

As was stated early in this discussion, it is essential that the electrical discharge shall emanate from the discharge electrode and travel to the collecting electrode if normal precipitation is to be accomplished. When materials are collected which tend to form porous dielectric deposits, it is, therefore, essential that conditions must be so changed as to prevent the formation of such a deposit. This can be done in several ways. The material to be precipitated may be changed through the introduction of substances which will cause the deposit to become conducting, as, for example, the addition of acid mist, carbon smoke, or any other convenient conducting material. Or, the gases may be so changed as to cause a surface leakage over the particles composing the deposit, which is often readily accomplished through the addition of moisture to the gases to increase the humidity thereof. Or, conducting materials may be added directly to the electrodes, as, for example, water or acid. Only a slight conductivity is necessary, as a current density as low as one milliampere per 30 sq. ft. of deposit is not uncommon. We are all familiar with the effect of humidity on the operativeness of electrostatic influence machines, where a slight surface leakage is sufficient to prevent the building up of a charge. A similar leakage is amply sufficient for drawing the charge through the deposit in a precipitator where conditions will permit humidifying the gases.

It is obvious that some deposits will exhibit much more serious effects than others, depending upon the degree to which they will accumulate a surface charge. In certain cases the discharge from the deposit, or back ionization, as it has been called, is sufficiently heavy to be clearly visible when viewed in the dark. Under such conditions, precipitation virtually ceases, the current flow will mount to many times its normal value, and the arcing voltage may be lowered as much as 50 per cent below its normal value. In other cases the back ionization is very mild and this will be manifested by a correspondingly small decrease in the arcing voltage. In such cases it will often be noticed, with a mixed dust and fume, that the decrease in efficiency will be greater on the fume than on the dust, possibly due to the fact that the relatively heavy dust particles can be shot through the thin reverse discharge caused by the back ionization, while the relatively light and small fume particles are arrested in their course, discharged, then recharged and repelled from the collecting electrode.

From a practical point of view, this can all be summarized by saying that the deposit upon the collecting electrode should, at all times, be kept conducting.

A series of investigations recently conducted by E. Anderson and G. H. Horne, has disclosed some interesting and valuable information on the relationship between various factors bearing upon precipitation efficiency. This information can be summarized in a number of conclusions. Of primary importance is the relationship between precipitation efficiency and gas volume. Anderson has shown that the curve expressing this relation follows an exponential equation. Secondly, he has shown that with a given definite gas volume, the precipitation efficiency is a function of the length of discharge electrode and again follows an exponential equation. Thirdly, Anderson and Horne have shown that each combination of gas and fume has certain specific properties when considered from a precipitation viewpoint, and that these properties can be expressed numerically as a constant to be included in the precipitation equation.

The value of these three conclusions cannot be overestimated, as they bring order out of chaos in the mass of puzzling and apparently conflicting data that have been accumulated during the past ten years. All that is necessary now is to determine the value of the precipitation constant that applies to any specific problem, and all other considerations then follow in a perfectly orderly manner, according to definite mathematical relationships. The precipitation constant can be easily determined by experiment, or, where a familiar problem is under consideration, it may be drawn from experience. We will pass over the relationship between different types of electrodes, as discussion of these factors lies outside the scope of this paper, being in the province of the specialized engineer. The choice of type of treater, type and size of electrodes, electrode spacing, operating voltage, etc., are dependent upon engineering considerations, and can be dictated by experience only. The important generalized conclusion which it is desired to emphasize here, is that all types of precipitators behave in a similar manner, the effectiveness of one being expressible in terms of the other, and that after allowance is made for the type of treater, precipitation efficiency is then

expressible in the terms of an exponential equation, which equation involves a precipitation constant expressing the properties of the fume-laden gas under treatment, and which has as its variables the length of discharge electrode and the gas velocity.

The following table shows the close agreement between calculated and observed values for precipitation efficiency:

Type of Treater	Character of Fume	Gas volume cu. ft. per min.	Efficiency Observed per cent	Efficiency Calculated per cent
Pipe..............	Potash fume	23,000	86	86
Plate..............	Potash fume	18,000	75	71
Pipe..............	Cement dust	150,000	94	92
Pipe..............	Metallic chloride	15,000	97	98.8
Pipe..............	Lead fume	102,000	82	85
Plate..............	Bismuth fume	5,000	90	92
Transverse screen	Potash fume	1,000	73	75

Considering the wide variation in both the character of fume and the gas volumes handled, the agreement between calculated and observed efficiency values is quite satisfactory.

With this definite knowledge at our disposal, it is now possible to calculate the optimum size of a precipitator for any specific commercial installation where the most economical recovery of valuable dust or fume is under consideration. A. A. Schmidt has developed a formula to be used for this purpose, which equation is of the form

$$x = a\left(\frac{\log \dfrac{b}{c \log d}}{\log d}\right)$$

In this equation a is the gas volume to be treated, b is a function of the unit cost of the precipitator, the rate of interest and depreciation and cost of labor and power. The value of the solids carried by the gases is represented by c, d is a function of the specific precipitation rate for the fume or dust considered, and x is the optimum size of the precipitator.

It should be emphasized that the equations pertaining to precipitation efficiency apply only while normal precipitation is being performed. If a porous dielectric deposit is accumulated upon the electrodes and back ionization is established, normal precipitation is obviously interfered with and these equations can no longer be applied.

It should also be emphasized that the precipitation constant is in itself a variable and that its value is only constant for a specific set of fume and gas conditions, and shifts with changes in gas composition, temperature, fume composition, fume concentration, physical state of subdivision of dust or fume, etc.

To make these last statements clear, it might advantageously be said that it is not only the average value of the precipitation constant that is of interest in designing a commercial installation, but consideration must also be given to the limits through which the value of this constant will fluctuate with variations in factory operations. For example, in treating the gases from a single copper converter, different precipitation constants apply at different stages in the converting operations. If the matte fed to the converter contains appreciable quantities of lead and zinc, the gases arising from the first part of the blast will carry a lead and zinc fume, while during the latter part of the blast the gases will carry essentially fine copper pellets or dust mixed with some copper fume. Also, a constantly rising temperature must be dealt with. Furthermore, as lead and zinc fumes have the faculty of forming deposist which easily lead to back ionization, care must be taken to insure at all times the deposition of a conducting deposit. In designing a plant to take care of such a problem, a precipitation constant must be chosen which will represent the most difficult conditions to be encountered under the varying operating conditions. The example chosen is, of course, an extreme case, and the engineer is rarely called upon to design a plant to operate on such a varying load. Usually the precipitation constant will vary within rather close limits, and these limits can ordinarily be readily determined before design of precipitator is undertaken.

Anderson and Horne, in their investigation, have again confirmed earlier determinations upon the effect of voltage. It is now clearly established that precipitation efficiency rises rapidly as the voltage increases, and that for best results, the voltage on a precipitator should be kept as near the arcing point as is consistent with smooth operation. As voltage has a direct bearing upon precipitation efficiency, the question will be asked as to why this variable has been ignored in the previous discussion. Although the relation between voltage and precipitation efficiency has been determined for the entire range, commercial installations are always operated at the maximum stress permissible with smooth operation, and consequently the voltage variable can be disregarded.

The purpose of this paper is merely to present some of the conclusions which have been drawn from recent investigations, and to make these available to the engineer. A detailed discussion of the actual equations used in designing precipitators, and calculations embodying their use, have been purposely omitted because, after all, the choice of precipitator types and the analysis of the factors entering into the phenomenon of precipitation, can be properly accomplished only by the experienced specialized engineer, and his ability to do this is part of his stock in trade. However it is hoped that present-day conclusions have been sufficiently clearly and fully set forth to show that the former puzzling and perplexing data and apparent anomalies have been coordinated into a consistent whole, and that, after all, the phenomenon of precipitation is consistent as well as relatively simple in its essential fundamentals.

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Electrical Engineering Features of the Electrical Precipitation Process

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Review of the Subject.—*In the beginning, the Cottrell Process of Electrical Precipitation was greatly handicapped by the fact that there did not exist standard electrical equipment which could be used to develop the necessary potentials under the severe conditions imposed by the mechanical rectifier, used for rectifying the high-potential alternating current. The transformers used were a constant source of trouble and annoyance. This condition delayed the rapid accumulation of accurate data pertaining to precipitation phenomena, since those engaged in the work were kept busy in merely maintaining a source of power.*

It was not long, however, before the electrical manufacturing companies were interested in the problems involved, and better transformers were produced. These transformers have now been developed to a degree which is very nearly the equal of the ordinary power transformers of the same voltage ratings. For several years there was a demand for higher and higher voltage ratings, owing to the belief that through the use of very high potentials and consequent large electrode spacing the size and cost of precipitators could be greatly reduced. Potentials as high as 250,000 volts were experimented with, but such high voltages proved to be impractical.

Transformers were finally standardized at a voltage ratio of 220 or 440 to 100,000 volts, with taps in the low tension to give 50, 62.5, 75, 87.5 and 100 kilovolts. The capacities were 10, 15 and 25 kv-a. The 100,000-volt transformer of 15-kv-a. capacity has been used in the majority of installations.

CONTENTS

SOURCE OF POWER

IN all plants in commercial operation today the low-tension current is supplied to the transformer in accordance with one of two systems. These are known as the synchronous motor system and the motor-generator system, and are shown by the wiring diagrams, Figs. 1 and 2 respectively.

In the synchronous motor system, the power is supplied to the transformer from one phase of the regular factory three-phase main. The mechanical rectifier is driven by a synchronous motor from which this system derives its name. This motor is a special type of synchronous motor and consists of a standard four-pole induction motor of three h. p. rating, the rotor of which has been slotted or under cut at four places in its circumference to emphasize the poles. It possesses the ability to pull into synchronism on voltages as much as 15 to 20 per cent below normal, and will deliver approximately two h. p. without slip. The greatest advantage of this system is its low cost. Its chief disadvantage is that the synchronous motor system requires careful attention on the part of the operators in starting up, first to secure the proper polarity, and then to observe that a slip does not take place after starting, due to momentary low voltage when the polarity could be reversed by the motor slipping one pole, it being ordinarily necessary to maintain the discharge electrode system at negative polarity to secure maximum precipitation efficiency. In addition to this, the voltage regulations must be accomplished either by means of an auto-transformer or variable resistance or induction regulator, or any combination of these. Further, in this system, the precipitator circuit is directly connected to the mains serving other departments of the factory, and any disturbances may be reflected back on these mains.

In the motor-generator system a motor is used to drive a single-phase four-pole generator which supplies power through the switchboard to the low-tension windings of the transformer, and this motor is also coupled to the rectifier. As the generator and rectifier are mechanically connected, the latter is always in synchronism with the current which it is rectifying. This system possesses the advantage of easy voltage regulation by means of the generator field rheostat. Furthermore, there is no electrical connection between the precipitator circuit and the factory mains, and this eliminates all possibility of disturbances from this circuit being reflected back on the factory mains. The greatest disadvantage of this system lies in its first cost

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and in the fact that a direct-current supply is needed for generator field excitation, which usually calls for a small motor-driven exciter.

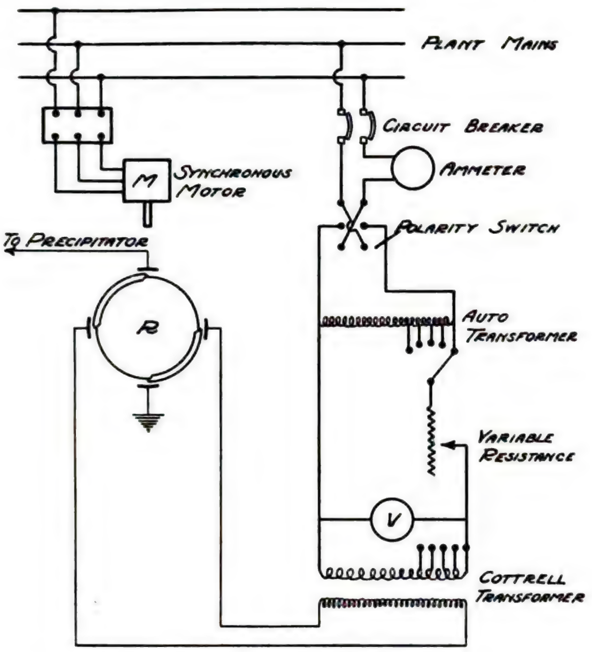

Fig. 1—Wiring Diagram—Synchronous Motor System

A third system has been proposed which, however, has never been used. In this the transformer would be eliminated and power taken directly from existing high-tension power lines through proper protection and switching devices, and the current rectified by a syn-

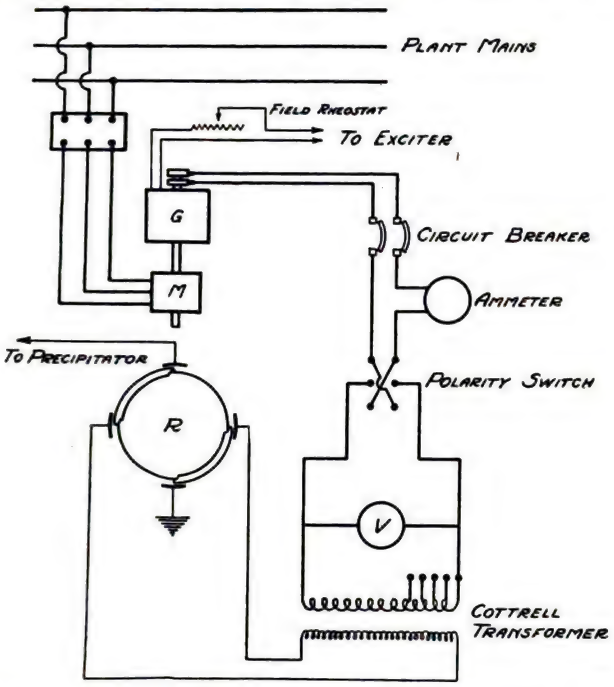

Fig. 2—Wiring Diagram—Motor-Generator System

chronous motor-driven rectifier. This system will probably never come into actual use as it is doubtful if any company would care to connect a high-tension line to this class of service.

There is no marked difference in the precipitation results obtained from either of the two systems in use, as the same voltage can be maintained on the precipitator by either system, and insofar as power supply is concerned, precipitator voltage is the important factor bearing upon precipitation efficiency.

Methods of Rectification

As indicated above, it is necessary to supply the discharge electrode system with unidirectional current in order to obtain maximum precipitation efficiency. This does not mean that a regular direct current is necessary. In fact, it has so far not been definitely proved that direct current possesses any inherent advantage over the pulsating unidirectional current obtained through the use of the mechanical rectifier.

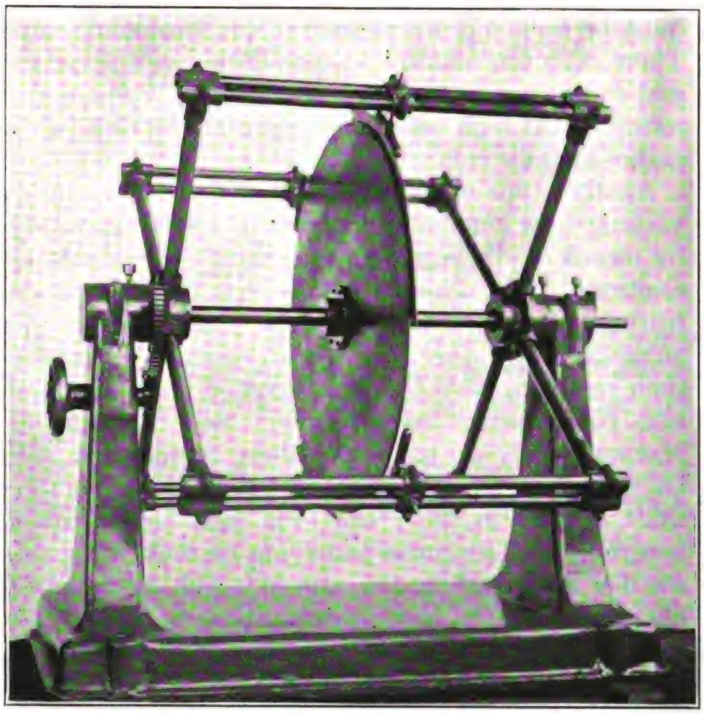

Fig. 3—Mechanical Rectifier

A typical mechanical rectifier is illustrated in Fig. 3. It consists of a bakelite disk to the periphery of which are attached two quadrant metal strips opposite each other, these constituting the moving conductors. The four stationary shoes are so mounted that they may be rotated about the disk through 90 deg. by means of a hand wheel, pinion and gear segment. The length of the stationary shoes and the length of the moving conductors determine the length of contact on the wave, and the position of the shoes about the disk, as adjusted by the hand wheel, determines the portion of the wave rectified. On the rectifier illustrated, the shoes cover approximately 25 per cent of the wave. Mechanical rectifiers of this general type are the only rectifiers which have so far proved successful in commercial operation, and, as a result, are the only kind in use at this time. While they are far from perfect in many respects, they do possess the advantage of sub-

stantial construction and simplicity of operation requiring a minimum of attention. In other words, they embody features of reliability not yet attained in other types. The greatest single objection to them is that the high-tension circuit is made and broken in air, generating high-frequency oscillations, which place abnormal electrical strains on the transformer. Apparently these oscillations do not markedly affect the efficiency of precipitation, at least no tests have shown any appreciable lowering of efficiency from this cause. Another objection to the mechanical rectifier is that it is noisy in operation due to the arc which is drawn out at the trailing end of the rotating segments. However, the noise as well as the oscillations may be fairly well damped out by the use of proper resistance in the high-tension circuits. A further objection to the mechanical rectifier is its low efficiency due to the air gap which must be broken down at each of the stationary shoes. There is an unavoidable voltage drop over the rectifier and it has not been found possible to eliminate this, owing to the high peripheral speed of the disk, which makes metallic contacting impractical.

Another type of rectifier is the kenotron, which is a vacuum tube conducting current in one direction only by means of electronic emission from an incandescent electrode. This type of rectifier has many promising features as it does not possess a number of the disadvantages of the mechanical rectifier. However, such rectifiers have the disadvantage of being fragile and consequently require much care in handling. Moreover they do not stand short circuits and must be protected by a system of automatic relays since short circuits in the precipitator may be of frequent occurrence. The current-carrying capacity of such a rectifier is limited by the rate at which electrons are liberated from the incandescent filament. The life of such a rectifier is limited, but with the kenotron this has now been extended to approximately 2500 hours. As yet, no large commercial precipitation installations have been made with kenotrons as the sole means of rectification. Investigations are now under way at one of the larger smelters in the United States in which comparative studies are being made of the kenotron and the mechanical rectifier with the object of determining their respective merits over long periods of operation.

A third method of rectification is by means of the air blast rectifier. This method has not been carried beyond the experimental stage as it was found to possess all of the disadvantages of the mechanical rectifier in an aggravated form. This rectifier consists of a discharge point facing a plate. The pointed rod is located so as to project from a tube through which compressed air is blown around the point toward the plate. This apparatus acts as an electric valve, allowing only the positive discharge to flow across the gap to the plate. The only advantage which the air blast rectifier possesses is cheapness.

Direct Current

So far as is known, there has been only one serious attempt made to produce a direct-current generator for precipitation work. This was made several years ago by the Girvin Electrical Development Company of

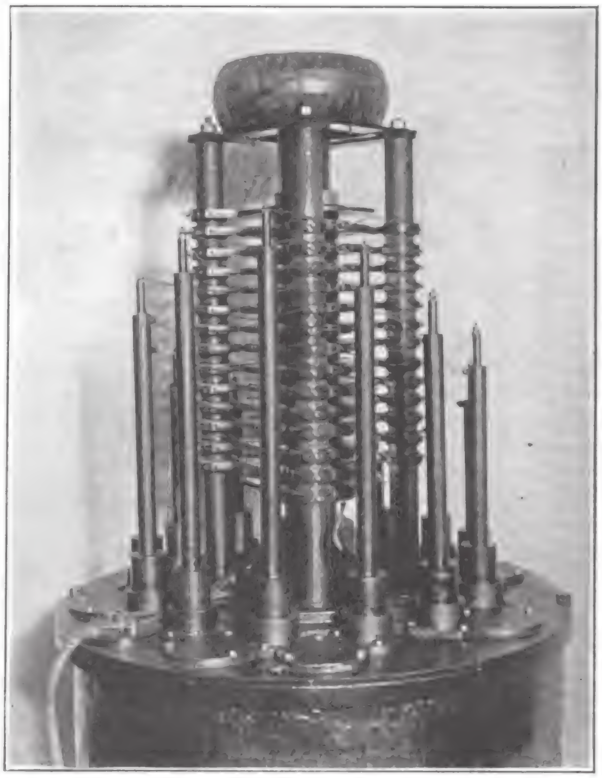

Fig. 4—Commutator of D-C. 50,000-Volt Girvin Generator

Philadelphia, working in conjunction with the Research Corporation of New York. Several machines were built of about 10-kw. capacity which delivered current at 50,000 volts. Also one 75,000-volt generator was built. Fig. 4 shows the commutator of one of these

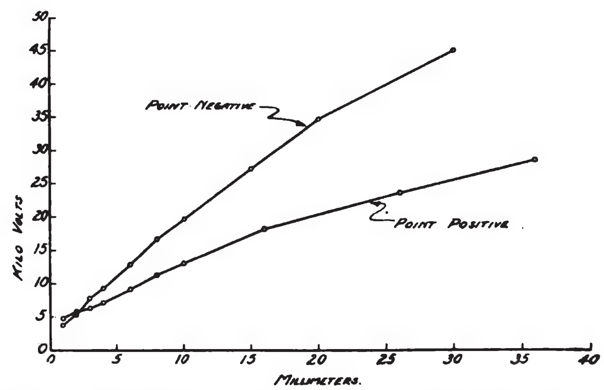

Fig. 5—Arcing Voltage between Point and Sphere at Short Distances

generators. These machines were of the vertical type, belt-driven, with a rotating field and provided with intermediate commutating poles. The armature coils were submerged in oil. The case carrying this oil being partly located in the magnetic field, was made of bakelite.

The individual coils of the armature were brought up to a commutator which consisted of a number of disks one of which served as a commutator for each armature coil. The disks were interconnected so as to add the voltages of all coils and deliver the power to a single high-tension lead. The other end of the system was grounded. These machines were 33 inches in diameter and 62 inches high, making a very compact unit when the capacity and voltage rating are considered.

Comparative tests made between one of these generators and a mechanical rectifier indicated that the generator gave slightly better results, so far as precipitation efficiency is concerned, but the superiority was not sufficiently great to warrant further development work.

Relation between Precipitation and Impressed Voltage

In the foregoing discussion the main features of the apparatus and methods used in producing a source of

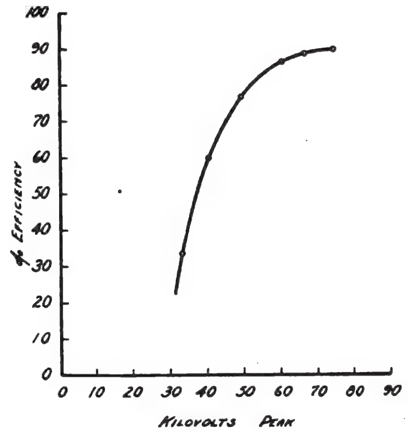

FIG. 6—RELATION BETWEEN PRECIPITATION EFFICIENCY AND PEAK KILOVOLTS IMPRESSED ON PRECIPITATOR
Typical Curve

power for electrical precipitation work have been discussed. It is interesting to note some of the relations between voltage and precipitation efficiency.

The measurement of voltage by means of the needle point spark gap, is well-known. If one of the needles is replaced by a smooth, clean flat plate, we have what is analogous to a precipitator, the needle point corresponding to the discharge electrode and the plate to the collecting electrode. With such a "point to plate" arrangement, laboratory studies may be made of some of the fundamental factors involved in electrical precipitation. It can be shown that rupture, or complete electrical breakdown, of the air between the point and plate for most spacing will take place at widely different voltages, depending on whether the point is positive or negative. This is shown by the two curves of Fig. 5. It will be noted that the curves cross at about 2 mm. and that at shorter distances the arcing voltage is greater when the point is positive, while for all spacings above 2 mm. the arcing voltage is greater when the point is negative. This is one reason why the use of negative polarity on the discharge electrodes in electrical precipitation is preferable. A second reason for using negative polarity is that usually the precipitation efficiency is higher even with equal impressed voltages.

In a precipitator, under actual working conditions, the difference in the arcing voltage between positive and negative polarity is not so great as found in the

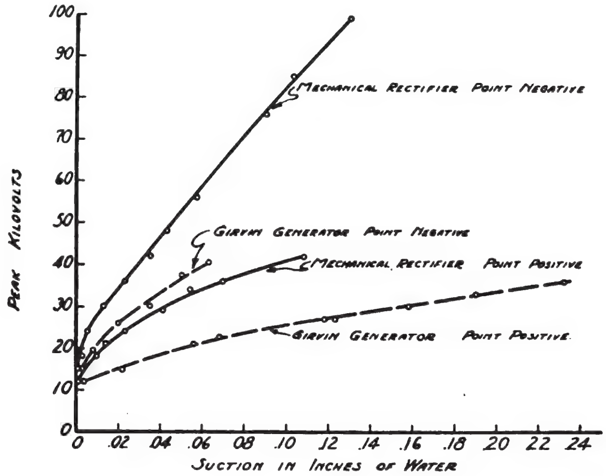

FIG. 7—RELATION OF SUCTION CAUSED BY ELECTRIC DISCHARGE, TO PEAK KILOVOLTS
Point mounted 6 cm. above grounded plate

point to plate investigation in the laboratory, results of which are indicated in Fig. 5. However, there is usually a substantial difference in favor of negative polarity.

Fig. 6 illustrates the relation existing between the voltage impressed on a precipitator and its precipi-

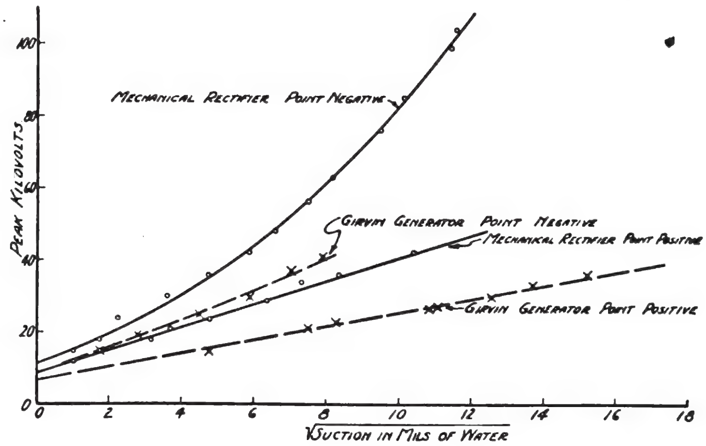

FIG. 8—RELATION OF $\sqrt{\text{SUCTION}}$ CAUSED BY ELECTRIC DISCHARGE, TO PEAK KILOVOLTS
Point mounted 6 cm. above grounded plate

tation efficiency. It will be noted that this curve flattens out toward the top and the higher voltages are not accompanied by a corresponding increase in efficiency. The highest point shown on the curve in Fig. 6 is 2000 volts under the normal arcing voltage of the precipitator on which the tests were made. This curve, therefore, shows the fallacy of the belief which

has often been expressed in the past, namely, that the last few volts, just under the arcing voltage, are particularly effective.

The fundamental differences between the positive and negative discharge as they affect precipitation, are not well understood. A visual difference is observed in the corona of the two. The positive corona manifests itself in rather long shifting brushes, while the negative is of a steady, bright beadlike character. From such an observation it may be concluded that with positive discharge the gas is ionized to a greater distance from the conductor than with the negative discharge. On the basis of this assumption, it is not surprising that the arcing distance for a given voltage is greater when the point is positive than when it is negative.

In connection herewith, some study has been made of the electric windage established about a discharging point. This was done by using the point to plate method described above, with the exception that in this case the pointed rod was hollow, the discharge taking place from the rim of a hole 0.04 inch in diameter. This pointed rod was fitted to a brass tube and was connected to a draft gage by means of rubber tubing. Fig. 7 shows curves of the results obtained with a constant spacing of 6 cm. between the point and plate. The curves marked "Girvin" are those obtained with the 50,000-volt generator previously described. The other two curves were obtained by using a mechanical rectifier. It will be noted that in all cases, the suction created about the point is several times greater when the point is positive than when it is negative. From some further calculations and curves which are shown in Fig. 8, it seems that the suction established around the positive point follows a quadratic law so that the square root of the suction is proportional to the voltage. The suction created by the negative point, however, apparently does not follow the same law. From these results one might be led to conclude that this difference in windage may have something to do with the difference in the arcing voltage, but this does not seem to be the case for with the air blast rectifier, an artificial draft about the negative point does not lower its arcing voltage, but, in fact, slightly increases it.

Power Consumption

The power consumption of a precipitator, having clean electrodes and ordinary air as the dielectric medium, appears to follow the laws of dielectric phenomena discussed by F. W. Peek, Jr., in his "Dielectric Phenomena in High-Voltage Engineering." On the other hand, the power consumption in a normally operating precipitator having the electrodes covered with deposits of fume or dust, and having furnace gases as the dielectric, is influenced by a number of factors which have not as yet been fully investigated.

Gases arising from combustion or other chemical reactions may be highly ionized, and the current flow will consequently be increased unless means are employed to remove the ions before the gases reach the precipitator. Then, too, the temperatures of the gases may be as high as 600 deg. cent., and this in itself may cause variations over and above those which would be expected from the corresponding reduction in the gas density. The nature of the deposits on the electrodes has a distinct bearing upon the power consumption of the precipitator. Thus there may be deposits on the collecting electrode which act as insulating coverings, and therefore simply act to reduce the gradient at the discharge electrode, and consequently also reduce the current flow. Likewise when the discharge electrode becomes partly covered with such a deposit, the current flow is reduced, although in this case the reduction is brought about by a decrease in the effective length of the discharge electrode.

Furthermore, deposits may form on the collecting electrode constituting discontinuous dielectrics, which may so greatly modify and increase the ordinary potential gradient near the surface of this electrode as to cause ionization to set in at this electrode also. An effect is thus produced which so far as power consumption is concerned, is equivalent to an increase in the length of the discharge electrode.

Although few data have been accumulated on the quantitative effect of such deposits on the power consumption, the effects of such deposits on the arcing voltage and on precipitation have been discussed in the literature[1] on the subject.

The following table will serve to show how much deposits may modify the ordinary operating conditions. This table was made up from data obtained by E. R. Wolcott and the writer, and shows the effect of such deposits on the arcing voltage between a point and a plate, six centimeters apart:

Material on plate		Arcing voltage kv. peak
Plate clean	point negative	120
Mica	" "	50
Sulphur	" "	50
Glass wool	" "	50
Varnished cambric	" "	70
Filter paper	" "	90
Writing paper	" "	118
Writing paper crumpled	" "	90
Edge of glass plate	" "	65
Asbestos	" "	100
Plate clean	" positive	45

From this table it is seen that the greatest effect produced by any of the materials is not as pronounced as that caused by reversing the polarity of the point. Apparently a minimum arcing voltage is reached with the point positive, and the effect of deposits on the plate under a negative point is to lower the arcing voltage to a value which approaches that when the

1. E. R. Wolcott, *Physical Review*, N. S. Vol. XII, No. 4, October, 1918, and E. Anderson, *Chemical and Metallurgical Engineering*, Vol. XXVI, No. 4, January 25, 1922.

point is positive. So far as is known, no material has been found which reduces the arcing voltage with the point negative to a value as low as that which applies when the point is positive. On the other hand, no materials have been found which lower the arcing voltage when the point is positive. In fact, it has been shown that a point may be substituted for the plate when the plate is negative without lowering the arcing voltage.

The effect of a discontinuous dielectric is illustrated in Fig. 9, which is from a photograph of the corona formed at the positive plate, by a thin sheet of mica having a small hole. Naturally, the current flow and power consumption must be tremendously affected by conditions such as these, and the problem of obtaining consistent data from different installations is very difficult.

However, there are installations where the above mentioned disturbing influences are a minimum. Data

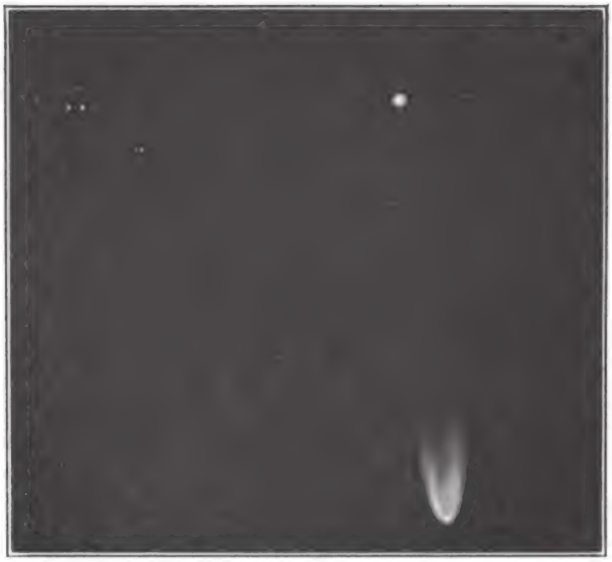

FIG. 9—CORONA FORMED AROUND HOLE IN MICA SHEET PLACED UPON POSITIVE PLATE

TABLE 1—POWER DATA

112 Pipes 8 inches internal diam. by 13 ft. 0 in.
With Still Air at 70 deg. fahr.

(See Figs. 10 and 11.)

High Tension				Low Tension					Sq. Rt. Watts		
Peak Kv.	R. M. S. Kv.	M. A.	Watts	Volts	Amperes	Watts	Losses Watts	Watts Net to treater	H. T.	L. T. Gross	L. T. Net
13	10.8	2.2	24	80	0.0	200	275	0	4.9	14.1	0.0
14	12.8	5.6	72	100	0.0	334	320	14	8.48	18.2	3.7
17	14.3	8.0	114	110	0.0	434	348	96	10.68	20.8	9.8
19	15.3	14.0	214	120	2.0	667	428	239	14.62	25.8	15.4
20	15.8	17.5	276	130	8.0	900	630	270	16.60	30.0	16.4
22	16.8	21.0	353	140	13.0	1134	818	316	18.78	33.7	17.8
24	17.8	28.0	498	150	19.0	1467	1060	407	22.30	38.3	20.3
26	20.2	56.3	1137	160	27.5	2667	1442	1225	33.70	51.6	35.0
31	22.2	77.0	2150	170	46.0	4834	2455	2379	46.40	69.5	48.8
34	23.7	113.6	2669	180	54.0	6000	3043	2957	51.80	77.4	54.4
35	24.2	137.4	3320	190	62.5	7234	3765	3469	57.60	85.0	58.9
38	26.2	166.0	4350	197	74.0	8667	4852	3815	65.90	93.1	61.7
32	23.7	123.0	2870	180	51.5	5500	2863	2637	53.60	74.2	51.3
28	21.2	80.0	1695	160	36.0	3667	1842	1825	41.15	60.5	42.7
16	13.3	11.6	154	110	0.0	434	348	96	12.40	20.8	9.8
19	14.8	15.0	222	120	2.0	667	428	239	14.90	25.8	15.4
22	16.8	23.3	392	140	12.0	1000	783	217	19.80	31.6	14.7
26	22.2	76.7	1702	160	36.0	3734	1842	1892	41.25	61.1	43.4

TABLE 2—POWER DATA

112 Pipes 8 inches internal diam. by 13 ft. 0 in.
With gas at 170 deg. fahr. and 9 feet/sec. vel.

(See Figs. 10 and 11.)

High Tension				Low Tension					Sq. Rt. Watts		
Peak Kv.	R. M. S. Kv.	M. A.	Watts	Volts	Amperes	Watts	Losses Watts	Watts Net to treater	H. T.	L. T. Gross	L. T. Net
51	39.5	146	5770	216	64	9667	4082	5582	76.0	98.3	74.7
47	36.0	128	4610	205	58	8170	3480	4690	67.8	89.8	68.5
41	31.6	130	4110	200	57	7667	3370	4297	64.1	87.6	65.5
38	30.1	106	3210	190	48	6000	2685	3315	56.6	77.4	51.6
32	24.6	36	900	170	20	1900	1195	705	30.0	43.6	26.6
30	23.7	28	664	160	15	1367	972	395	25.7	36.9	19.9
28	23.0	21	483	150	10	1067	760	307	21.9	32.6	17.5
26	22.2	16	355	140	5	734	573	161	18.8	27.1	12.7
22	19.7	8	176	120	0	334	378	0	0.0	18.2	0.0
26	22.2	19	422	140	5	834	573	261	20.5	28.9	16.2
30	24.2	28	678	160	16	1434	997	437	26.0	37.8	20.9
36	27.1	92	2490	180	43	5134	2363	2771	49.9	71.6	52.6
39	29.1	124	3610	190	56	6867	3235	3632	60.0	82.8	60.2
41	30.6	152	4650	200	67	8667	4240	4427	68.2	93.1	66.5

from such installations indicate that Peek's fundamental equation for corona loss does apply, at least approximately. This equation is:

$$P = C^2 (e - e_0)^2$$

For the purposes of precipitation calculations, let

P = power required in watts
e = voltage impressed on treater in kilovolts peak
e_0 = the critical disruptive voltage in kilovolts peak
C = a factor representing the slope of a line resulting from plotting $\sqrt{P}$ against e

The following are representative tabulations of the power data obtained when 112 pipes 8 inches internal diameter by 13 feet 0 inches long were energized at various voltages. While the pipes used in these tests were of wood, they possessed good conducting qualities since the material collected was a mist of salt solution, and the pipes were, therefore, moist and impregnated with salt:

The columns headed "Losses" represent the losses between the input to the transformer and the input to the precipitator. These losses were established in the same manner that is used to determine iron and copper losses in transformers, *i. e.*, by establishing one curve of losses when the precipitator is disconnected with various voltages impressed on the transformer, rectifier and high-tension lines, and another such curve for the $I^2 R$ losses when the precipitator line is grounded, and the transformer current varied. With these losses established for the particular electrical equipment used, it is possible then to calculate the net power input to the precipitator from the instrument readings in the low-tension circuit. This is given in the column headed "Watts net to treater." Under the general heading "Sq. rt. watts," the heading "H. T." is the square root of the power in watts as calculated from the high-tension current ("M. A.") and the r. m. s. kilovolts.

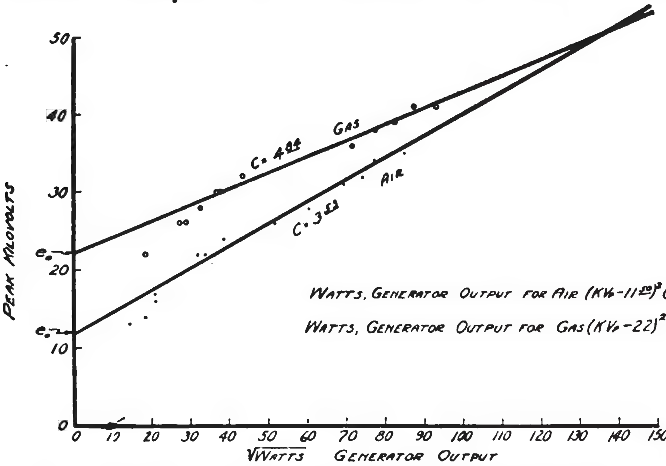

FIG. 10—POWER DATA PLOTTED—PIPE PRECIPITATOR

The heading "L. T. Gross" is the square root of the generator output in watts. The heading "L. T. Net" refers to the square root of the "Watts net to treater." The first table gives the values obtained when the pipes contained still air at 70 deg. fahr. The second table gives the values obtained when the treater was operating on a mist-laden gas at the temperatures and velocity indicated.

Fig. 10 shows two lines plotted from the above data, one for air and one for mist-laden gas. In this case the square root of the generator output (input to transformer) in watts (column marked "L. T. Gross") is plotted against the voltage impressed on the precipitator in kilovolts peak. It is possible to use the generator output in this way as well as the net input to the treater, because the losses are principally made up of $I^2 R$ losses in the transformer and at the rectifier. At least the evidence of the curves indicates that there is little error introduced by so doing. The peak voltage has been used instead of the r. m. s. because of the comparative ease of obtaining readings in terms of peak voltage.

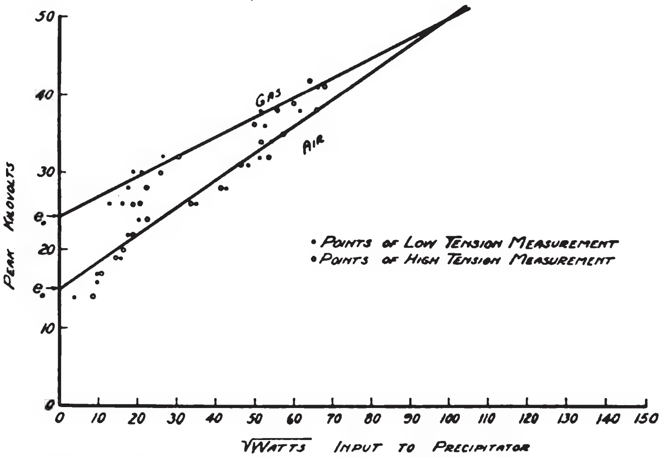

FIG. 11—POWER DATA PLOTTED—PIPE PRECIPITATOR

From an inspection of these curves, the differences in the values of e_0, and of C, the slope of the lines will be noted. It will also be seen that the power for the "air" curve is greater than for the "gas" curve, up to a voltage of approximately 50 kv., where the curves intersect.

Fig. 11 shows similar curves plotted against the square root of the net power input to the treater. The values of the power as obtained from the low-tension readings are seen to be in fair agreement with those obtained directly from the high-tension instruments. These curves also show the same relative values of e_0 and C as in Fig. 10.

CONCLUSION

It is, of course, impossible to draw any general conclusions from the data here presented, except that it appears the power consumption does follow the quadratic law given by Peek, and that this law is applicable to electrical precipitation. However, it should be said that certain experimental data indicate that the fume or dust carried in suspension in the gases may affect the electric discharge and may decrease the power consumption. From the increase in the value of e_0 for "gas" over that for "air," shown in the curves, it might further be concluded that fume also may cause a considerable increase in the corona starting voltage.

The foregoing data and discussion show that Peek's expression for corona loss may be used as a means of interpreting electrical precipitation power data.

The Status of Railroad Electrification

BY CALVERT TOWNLEY
Westinghouse Electric & Manufacturing Co., New York

WHEN we electical engineers have discussed railroad transportation we have always done it from the standpoint of proving how desirable it is for the steam railroads to electrify, and when we have invited our steam railroad friends to participate in our discussions, they usually refrain from courtesy or some other reason from telling us absolutely and entirely what they think of us. It has therefore occurred to me that it might be worth while for an electrical man to say a few words about the railroad man's natural objections to electrification and to give some of the reasons why he is not always willing to fall upon our necks and welcome us as saviours.

Having enjoyed for many years an association with the big railroad system which serves this community, I have had an opportunity to learn something of the railroad man's point of view from the inside.

In the first place, electrification is very expensive. It involves not a small but a tremendous addition to the investment per mile, with the consequent difficulties not only of earning the additional interest charges thereby involved, but also those of financing—of raising the money. These are by no means minor objections. The day has gone by when the management of a railroad property can have a free hand in issuing securities. Through their various governmental agencies the public has established a strict supervision over railroad earnings, is reluctant to permit the capitalization of values created by earning power and is prone to regard railroad securities as having so stable a value that their yield must be limited to a minimum annual interest with little opportunity for the stockholders of the road to obtain large profits from courage and initiative; that is to say, stated in another way if a railroad by far-sighted and wise expenditures should be able to earn a rate of return such as is freely permitted and often applauded in private industry, such as for example as 15 per cent to 20 per cent per annum, it is most probable that this additional yield would be shortly taken away from it by a forced reduction in its rates. I am one of those who believe this public policy is founded on a misconception; is in fact practically an economic crime, because I think it is obvious that if a dollar invested in a railroad is not permitted as good a chance as one invested in a shoe factory or a flour mill, that dollar will tend to go into the factory or mill and not into the railroad, with the consequent hampering of that continued improvement and expansion of our transportation facilities so necessary to progress. I cannot escape what seems to me to be the obvious logic that if it be equitable for the public to prescribe a maximum rate of return on a railroad or any other investment, it should, as a necessary corollary, guarantee the same investment not less than a minimum return. However our public policy has been pretty firmly established by now so that what I think about it is of only academic interest.

The art of estimating in advance the cost of new construction, no matter if practised by the most competent engineers, has never reached or even approached perfection, therefore, where such large expenditures as those necessitated by electrification are contemplated it is always possible due to this fact and due to unforeseen contingent expenses that the estimated costs will be considerably exceeded. A combination of this contingency with the knowledge that should greatly increased profits result, the road may be deprived of them through the medium of rate reductions, may well cause the responsible executives to go slowly.

Long experience has demonstrated the necessity and established the practise of well-defined and rather rigidly restricted departmentalization of railroad construction and operation; that is to say, the construction, operation, traffic and financing are each in charge of a responsible official who concentrates his attention each on his own department and who is most punctilious in keeping out of every other sphere. This practise results of course in a high degree of efficiency in the conduct of each department and is obviously dictated by a wise policy. However, it has the disadvantage of dividing the responsibility for general results and makes for a tendency to put departmental success ahead of general prosperity.

Electrification upsets some of the fundamentals around which steam railroad practise has been built up, namely, it practically substitutes an unlimited for a limited motive power. This fact is well-known to us all but it is so fundamental and so far reaching in effect that it will bear restating and emphasizing many times. I refer of course to the fact that a steam locomotive which carries along its own boiler and is therefore in fact its own power house, is limited in the tractive effort it can exert by the steam which can be generated by that boiler, whereas the electric locomotive being only a translating device can call upon the entire capacity of all the power houses connected to the system. On account, therefore, of the large excess in such power house capacity over any possible demands of an individual train, on account also of the characteristic of electric motors to continue to exert more and

Address delivered before the Connecticut Section of the A. I. E. E., May 23, 1922.

more power even to the point of self destruction, and further on account of the possibility of operating two or more electric locomotives together in absolute synchronism with one crew and the consequent possibility of getting any desired weight on the drivers, there is practically no limit into the amount of tractive effort that may be utilized for any one train.

The consequences resulting from these facts are rather startling, for example, the long established and accepted practise of calling 2 per cent the maximum grade over which a desired schedule may be made goes into the discard and much steeper grades become entirely practicable, likewise the tonnage and speed of freight trains previously limited by the power of a steam locomotive to pull is no longer so limited. Freight trains may be as long as the structural strength of the freight cars will permit or as may be handled in the yards and on the sidings. Schedule speeds may be increased to any point considered safe for the track and equipment, being no longer limited by the steaming power of the locomotive. Instead of accelerating from a stand still at the rate of one-quarter of a mile per hour per second as is common steam locomotive practise, passenger trains may be accelerated at the rate of from one mile to one and one-half miles per hour per second.

We have always considered the above fundamental change as offering a wonderful opportunity for the improvement of traffic and they do offer such improvement but to get all the possible benefits requires the cooperative effort of the construction, operating and the traffic departments. It disturbs the existing order to a very considerable extent and redistributes the proportionate burden of expense among the different departments concerned so that any departmental head may be faced with the necessity of taking on some additional burden in his own department without any compensating advantage, *i. e.* the advantage goes to another department. In view of the well established relationship between departments above referred to, railroad executives cannot be blamed if they regard such innovations with skepticism and retain a considerable reluctance toward their adoption.

The relation between railroad management and railroad labor is a source of continued and great anxiety. Owing to the meddling (and I use the word "meddling" deliberately and advisedly) of Federal and other outside agencies in what may be a well meaning but is certainly a misguided effort, there has grown up an inflexibility in both the duties and the pay of railroad labor unparalleled in any other industry. Changes in operating methods are very difficult. Now electrification immediately requires a lot of changes. Not only have the engine drivers all to be educated to a new art but the duties of the fireman are revolutionized. In fact, except as a source of insurance against the death or disability of the engineer while driving his engine, the fireman is not needed at all. A new type of man, the electrical line man and the electrical shop man is required and where a railroad operates its own power houses the power house crews are introduced. The transmission lines overlap two or more divisions of the road and confuse the duties of the division superintendents. The signal system has to be revamped. These and other features all tend to upset the existing order of relationship between the management and its labor, and the official whose duty it is to regulate these relations may be forgiven if he contemplates with extreme alarm the task presented to him.

Many if not all of the bunkers which I have mentioned are present on every railroad and you will note are not removed even if it is known that railroad electrification would be advantageous. On top of this come all the questions of the actual virtue of electrification itself. It is perfectly true and I think now very generally admitted that all electrifications heretofore made have been successful and that no road which has electrified would now consent to return to previous conditions.

However not more than about one per cent of the entire steam railroad mileage of the United States has been electrified as yet and the average railroad executive may be excused if he looks upon the existing examples as special cases and therefore as proving nothing with respect to his own particular problem. For example, the New Haven and the New York Central had to electrify out of New York City because of a law passed by the State of New York. The Pennsylvania had to electrify out of New York City in order to operate its subway river tunnels. The Norfolk & Western had a peculiar restricted neck to its bottle in the Elkhorn grades which would justify almost any expense to remove. In a like manner some special reason can be found for almost every large electrification project. However it is perfectly safe to say that the attitude of mind of the railroad man has materially changed so that the question always first asked some years ago "Can it be done?" has now been replaced by the entirely different question, "Will it pay?"

As many of you know, I have been and still am a consistent and an enthusiastic advocate of steam road electrification. In reciting the different objections of which I have spoken I do not intend in any way to indicate a change of opinion or a weakening of confidence but rather because I think it helpful to us all when we can look at any situation from the other man's point of view and because I firmly believe we can do the cause of electrification no greater harm than to ignore plain facts and out of well meaning but mistaken zeal advocate electrification where we are not reasonably sure that it will be economically right.

JOURNAL OF THE American Institute of Electrical Engineers

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Annual Convention

NIAGARA FALLS, ONT., JUNE 26-30

The Annual Convention of the Institute has just convened in Niagara Falls as this issue of the JOURNAL goes to press. With a registered attendance of over 950, the Convention promises to be one of the most successful in the history of the Institute. The program as announced in the June JOURNAL will be carried out in full.

A complete report of the Convention will be published in the August number of the JOURNAL and the discussion of the papers presented will be printed in a future issue.

The Pacific Coast Convention

VANCOUVER, B. C., AUGUST 8-11

PLANS for the 1922 Pacific Coast Convention have progressed to an extent which permits us to announce a complete program of the convention in this issue of the JOURNAL. While this program is still to be regarded as tentative it is expected that no essential modifications will be found necessary in the schedules published herewith.

Vancouver, Canada's Pacific gateway, offers numerous attractions to visiting members of the Institute. It is a progressive modern city of 200,000 inhabitants and the principal railroad center and seaport of Western Canada. It contains excellent hotels, numerous parks, attractive automobile drives, bathing beaches and golf courses, and is in the immediate neighborhood of some of the most impressive mountain scenery in North America. Its equable climate is especially conducive to all kinds of outdoor recreations and ample facilities are offered for motoring, golfing, yachting, bathing, tennis and other amusemehts.

The technical program for the convention, in addition to the formal engineering papers on a wide variety of subjects, contains announcements of a number of informal addresses and lectures on subjects of general engineering interest by well-known speakers. Tuesday afternoon, Wednesday evening and Thursday afternoon have been left open for special entertainment features to be announced later by the Convention Committee. It has been the aim of the committees in framing the convention program to offer a diversity of interest in the features scheduled which cannot fail to make the convention both pleasant and profitable.

TENTATIVE PROGRAM

Tuesday Morning, August 8

1. *Address of Welcome*, by His Honor Walter Cameron Nicholl, Lieutenant Governor of British Columbia.
2. *Address*, by William McClellan, President A. I. E. E.
3. *Power Development on the Colorado River and its Relation to Irrigation and Flood Control*, by O. C. Merrill, Secretary, Federal Power Commission.
4. *220-Kv. Transmission of the Southern California Edison Company and Some 220-Kv. Researches*, by R. J. C. Wood, Engineer, Southern California Power Co.

TUESDAY NOON

Luncheon Conference, Institute Officers and Sections' Representatives.

TUESDAY AFTERNOON

Entertainment.

TUESDAY EVENING

5. *Little Stories of Engineering* (An Address), by G. Faccioli, Electrical Engineer, General Electric Co., Pittsfield, Mass.
6. *Pictorial Symposium of Power Plant Comparisons* (Stereoptican talk).

Wednesday Morning, August 9

7. *An Overpotential Test for Insulators*, by G. W. Lapp, Lapp Insulator Co., Le Roy, N. Y.
8. *Failure of Disk Insulators on High-Tension Transmission Lines*, by Harrison D. Panton, Carolina Power and Light Co., Raleigh, N. C.
9. *Tests and Investigations on Extra-High-Tension Insulators*, by C. C. Farr, Prof. of Physics, Canterbury College, University of N. Z., and H. E. R. Philpott, Testing Engineer, Lake Coleridge Hydro-Electric Power Supply, Christchurch, N. Z.

HOTEL VANCOUVER—CONVENTION HEADQUARTERS

BUSINESS SECTION OF VANCOUVER

WEDNESDAY NOON

Luncheon for all members and guests in attendance.

WEDNESDAY AFTERNOON

10. *Conservation of Human Material*, by J. W. Upp, Mgr. Switchboard Dept. General Electric Co., Schenectady, N. Y.
11. *Coordination of Professional Engineering and College Training*, by E. E. F. Creighton, Research Department, General Electric Co., Schenectady, N. Y.
12. *Training to Think vs. Gathering Information*, by T. Milton, Manager, Chicago Branch, Electric Storage Battery Co.
13. *Engineering Graduates in Business*, by L. A. Ferguson, Vice-president, Commonwealth Edison Co., Chicago, Ill.

WEDNESDAY EVENING

Entertainment.

Thursday Morning, August 10

14. *Exciter Instability*, by R. E. Doherty, Designing Engineer, General Electric Co., Schenectady, N. Y.
15. *The Electrical Characteristics of Transmission Systems*, by H. B. Dwight, Electrical Engineer, Canadian Westinghouse Co., Hamilton, Can.
16. *Experimental Investigation on Wind Pressure Upon Overhead Electrical Conductors*, by Shungo Furui, Graduate Student, Stanford University, Cal.
17. *A Graphic Method for the Exact Solution of Transmission Lines*, by C. H. Holladay, Engineer, Southern California Edison Co., Los Angeles, Cal.

THURSDAY AFTERNOON

18. *Mountain Railway Fuel Consumption*, (An Address), by A. H. Babcock, Electrical Engineer, Southern Pacific Ry., San Francisco, Cal.
19. *Research* (An Address), by C. E. Skinner, Research Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

THURSDAY EVENING

Entertainment.

Friday Morning, August 11

20. *The Development of Telephotography*, by D. W. Isakson, Utah Power & Light Co., Ogden, Utah.
21. *Recent Conclusions Pertaining to Electrical Precipitation*, by W. A. Schmidt, Western Precipitation Co., Los Angeles, Cal.
22. *Electrical Engineering Features of the Electrical Precipitation Process*, by G. H. Horne, Engineer, Western Precipitation Co., Los Angeles, Cal.
23. *Electrical Precipitation of Solids from Smelter Gases*, by R. B. Rathbun, Research Dept., American Smelting & Refining Co., Salt Lake City, Utah.

FRIDAY AFTERNOON

Boat trip to Hydroelectric Plant of the British Columbia Electric Railway Co. Lake Buntzen boat will take the party from there to Wigwam Inn, Indian River, for dinner, returning to Vancouver in the early evening.

Rocky Mountain Electrical Exposition

SALT LAKE CITY, UTAH, OCTOBER 2-14, 1922

The Rocky Mountain Electrical Exposition to be held at Bonneville Park, Salt Lake City, Utah, from October 2 to 14, will be an event of note for this section of the country, which has had no annual electrical shows. It will be held under the auspices of The Rocky Mountain Electrical Cooperative League, with the active support of electrical interests, commercial interests and educational institutions of several states. Numerous lectures, explaining the advantages of electrical appliances and their operation, from a disinterested viewpoint, will be an attraction of the exposition. The exhibits will include practically every application of electricity. A feature of the electric display will be the "Regional" Arch.

Senator Marconi on "Radio Telegraphy"

On the evening of Tuesday June 20, 1922 at the Engineering Societies Building, N. Y., before a joint meeting of the Institute of Radio Engineers and the N. Y. Section of the A. I. E. E., Senator Guglielmo Marconi, Honorary Member of the A. I. E. E., presented a paper on "Radio Telegraphy." This paper called attention to new developments in the radio field and Senator Marconi demonstrated on a miniature set, before the audience of over 1100 engineers, the possibility of directing wireless waves to any point desired. His talk was followed by short speeches praising his work by Dr. M. I. Pupin of Columbia University and Major H. A. Armstrong. The Institute of Radio Engineers then presented Senator Marconi with their Medal of Honor, awarded by the Board of Direction to a pioneer of preeminent standing in the radio field, whose contributions to the field have added substantially to its development. An abstract of Marconi's paper follows.

ABSTRACT

The lecture first deals briefly with the early history of long distance radio communication.

The work carried out by the engineers and experts of the Marconi Company in England with electron tubes or triode valves shows that, according to their experience, greater efficiency can be obtained at present by a number of bulbs used in parallel than by the employment of large single-unit tubes.

Information is given in a general way in regard to recent practise in the design and construction of receivers with the object especially of improving selectivity, reducing interference, and concerning the possible speed of working.

The lecture also deals briefly with results obtained at receiving observation stations situated in various far distant parts of the world, where it has been ascertained that radio signals arriving from high-power stations situated at or near the antipodes of the observation stations, reach the receivers by

various ways around the earth, not always following the shortest great circle route, and also that at such places the electric waves coming round by different ways do in certain cases increase this effect on the receivers whilst in others interfere with each other.

It has also been noticed that apparently transmission is easier from west to east than from east to west, and that it may be necessary to modify somewhat the transmission formula for long distances.

It has also been ascertained that the most troublesome atmospheric disturbances or static usually come from the continents and not from the oceans.

The lecture further deals with a study of short electrical waves and the results which have been obtained with such waves of a length from 1 meter to 20 meters, and describes tests which show for the first time that electric waves of under 20 meters in length, used in connection with suitable reflectors, are quite capable of providing a good and reliable point-to-point, unidirectional system of radio over quite considerable distances.

The application of this system as a direction finder in aid of navigation and as a method for preventing collisions at sea, is also dealt with.

Institute Prize Awarded to Frank G. Baum

Early in 1921, as announced in various issues of the JOURNAL, a prize was established by the Board of Directors consisting of one hundred dollars and a suitable certificate, to be awarded to the author of the paper which is designated by a duly authorized committee of award as the most worthy paper dealing with the art of transmitting electrical energy over considerable distances, presented at a meeting of the Institute during the year 1921, by a member of the Institute.

In accordance with the procedure approved by the Directors, the committee of award, consisting of the chairman of the Meetings and Papers Committee acting as chairman, and the chairmen of the various technical committees, awarded this prize on May 24, 1922, to Mr. Frank G. Baum, for his paper entitled, "Voltage Regulation and Insulation for Large-Power Long-Distance Transmission Systems," which was presented at the Salt Lake City convention of the Institute in June 1921.

Announcement of this award was made at the recent Annual Convention at Niagara Falls, Ontario. Mr. Baum was not present, but in a telegram acknowledging receipt of notification of the award, he expressed his appreciation of the action taken.

Professional Engineers' Licenses in New Jersey

The State Board of Professional Engineers and Land Surveyors of New Jersey announces that it is now ready to furnish application blanks to all professional engineers desiring license to practise in the state of New Jersey. These blanks may be obtained upon application to the Secretary of the Board, Mr. Hugh A. Kelly, Trust Co. of New Jersey Building, Jersey City, N. J.

John Fritz Medal Awarded to Marconi

The John Fritz Gold Medal has been awarded for 1922 to Senator Guglielmo Marconi. for the invention ,of wireless telegraphy.

The medal will be formally presented to Senator Marconi at a meeting in the Auditorium of the Engineering Societies Building, 29 West 39th Street, at 8:30 p. m., Thursday, July 6. This meeting will be in the nature of an international celebration, marking not only the advance of science but the progress of closer relationships between American engineers and the engineers of Italy and other European countries.

Prof. C. A. Adams of Harvard University and Chairman of the John Fritz Medal Board of Award, will preside at the presentation ceremonies. Addresses will be delivered by James R. Sheffield, president of the Union League Club; Prof. Michael I. Pupin of Columbia University, and Mr. Swasey, noted engineer and philanthropist, the founder of Engineering Foundation.

Chairman Adams, has appointed the following committee to arrange for the presentation ceremonies: Benjamin B. Thayer, New York, chairman; George S. Webster, Philadelphia; Walter M. McFarland, New York; William McClellan, New York.

Previous to the ceremonies Senator Marconi will be the guest at dinner of the John Fritz Medal Board of Award at 7:30 p. m. at the Engineers Club, 32 West 40th Street.

The John Fritz Medal, established in 1902 in honor of John Fritz, who was the first recipient of the medal, is awarded annually for notable scientific or industrial achievement. The award is made by a board consisting of representatives from the National societies of Civil, Mining, Metallurgical, Mechanical and Electrical Engineers. Other recipients of the medal have included Lord Kelvin, George Westinghouse, Alexander Graham Bell, Thomas Alva Edison, Charles T. Porter, Alfred Noble, Sir William Henry White, Robert W. Hunt, John Edison Sweet, James Douglas, Elihu Thomson, Henry Marion Howe, J. Waldo Smith, George W. Goethals and Orville Wright. Last year the award of the medal was made the occasion of a journey abroad of a mission of thirteen distinguished engineers, by whom the presentation was personally made to Sir Robert Hadfield of London and Charles Prosper Eugene Schneider, of Paris, head of Creusot works. The visit of this mission formally laid the foundation of an international agreement purposing closer relations between the engineers of all nations.

Senator Marconi is at present visiting in the United States, and recently addressed a meeting of engineers in New York on the subject of "Radio Telegraphy." (See notice elsewhere in this issue.)

American Engineering Standards Committee

BIG STANDARDIZATION PROGRAM PROPOSED FOR ELECTRIC RAILWAY FIELD

A standardization program of considerable importance to the iron and steel, lumber, electrical, construction, chemical, railway and railway supply industries is presented in the submission by the American Electric Railway Association of 13 standards for approval by the American Engineering Standards Committee.

The specifications submitted to the A. E. S. C. follow:

For Approval as American Standards:

Nine-Inch Girder Grooved Rail
Seven-Inch Girder Grooved Rail
Nine-Inch Girder Guard Rail
Seven-Inch Girder Guard Rail
Joint Plates for Seven-Inch Girder Grooved and Girder Guard Rails
Joint Plates for Nine-Inch Girder Grooved and Girder Guard Rails
Specification for Galvanizing or Sherardizing on Iron and Steel

For Approval as Tentative American Standards:

Seven-Inch 80-pound Plain Girder Rail
Seven-Inch 91-pound Plain Girder Rail

For Approval as Recommended American Practise:

Specification for Materials for use in the manufacture of Special Track Work
Specification for 600-Volt Direct-Current Overhead Trolley Construction.

Four special committees will be appointed by the American Engineering Standards Committee to determine whether the

A. E. R. A. specifications are the standards which should be adopted for universal use in the United States. The principal organizations concerned will be asked to name representatives on these special committees, which will be as follows: A committee will conduct the investigation with respect to the acceptability to the industry of the specification for 600-volt direct-current overhead trolley construction; another committee to conduct the investigation concerning the specifications for wood poles and tubular poles; a third committee to study the specifications for galvanizing or sherardizing on iron and steel; and a fourth committee to go into the subjects of the remaining nine related specifications. The findings of these committees will be reported to the American Engineering Standards Committee as soon as the investigations are completed.

COLORS FOR TRAFFIC SIGNALS TO BE STANDARDIZED

At the conference on the standardization of colors for traffic signals held in New York on May 23 under the auspices of the American Engineering Standards Committee, there were present representatives of practically all of the big national engineering societies, safety associations, electric and steam railway interests, automobile dealers, manufacturers and users associations, police and traffic departments, insurance companies, and several departments of the federal government.

The conference agreed unanimously "that there should be national uniformity in the use of colors for signals" and that the detailed technical work involved in bringing about such uniformity should be carried out by a thoroughly representative sectional committee under the auspices and procedure of the American Engineering Standards Committee. Included in the scope of the work as defined were the following:

The use of colored lights on all highway vehicles.

Their use on all signals along highways and at curbs, both permanent and temporary.

Their use for highway crossing signals for steam and electric railways.

A coordinated relation of color, form position and number of signals.

A coordinated relation to systems of flashing, moving or other similar lights.

Colors for nonluminous as distinguished from luminous signals.

Recommendations on the use of colors for emergency exit signals.

Methods of specifying or defining colors for signals purposes.

Any other closely related matters which, in the opinion of the sectional committee, form a part of the subject to be considered.

Mr. A. H. Rudd, on behalf of the American Railway Association, presented a paper in which were summarized the general facts of the situation affecting the steam railroads, and suggested lines along which they would like to see standardization progress. While signal systems of different railroads differ in some respects, fundamentals are largely standardized. For the operation of trains these include: red for danger (stop); yellow for caution; and green for clear.

A paper by Mr. H. B. Flowers gave the experience of the American Electric Railway Association. The standard use for signals in electric railroad practise is; red for stop; yellow for proceed with caution; and green for proceed at schedule speed. Blue, purple and white are also used in a restricted way, for conveying special information or for safe-guarding special conditions.

A suggestion that yellow light be used in place of red for the tail light of automobiles brought forth spirited discussion during which Mr. Alden L. McMurtry of the Department of Vehicles of Connecticut brought up the point that any such major changes as this would require at least two years to be put into operation, because legislation would be required in most states.

On the motion of Dr. M. G. Lloyd of the U. S. Bureau of Standards, a resolution was adopted declaring it to be the sense of the conference that any sectional committee of the A. E. S. C. which takes up the standardization of colors for signals should endeavor to coordinate such standardization with existing standards for traffic purposes, such as those used in water and aerial navigation and on steam and electric railways.

The conference did not advocate the substitution of green for red as a danger signal, as was erroneously reported in certain of the daily papers through a misinterpretation of discussion at the conference. On the contrary, the ideas expressed at the conference were emphatically that red should be used to indicate danger and for no other purpose. In conformity therewith, it was suggested that green be substituted for red as the color for lights for emergency exits of public buildings as indicating paths that lead to safety.

No final technical decisions were reached at the conference, these being left to be worked out in detail by a thoroughly representative sectional committee.

Engineering Foundation

HYDRAULIC LABORATORIES IN THE UNITED STATES

A Directory of Hydraulic Laboratories in the United States has been compiled under the direction of the Hydraulic Research Committee of Engineering Foundation, the members of which are J. Waldo Smith, Chief Engineer, Board of Water Supply of the City of New York, and Silas H. Woodward, consulting engineer, New York. The book has eighty-four 7 by 10 inch pages and contains information concerning 49 laboratories in engineering colleges, industrial establishments and governmental bureaus. Only statements furnished by the person responsible for the laboratory have been used in each case. Indirectly, this information affords comparison of equipment in the various laboratories and suggests possibilities of greater usefulness in some instances. The information will be helpful to those contemplating the establishments of new laboratories, to persons desiring to have hydraulic tests or experiments performed, and to students choosing schools in which to pursue the study of hydraulic engineering.

Persons desiring copies of the Directory of Hydraulic Laboratories, or more information regarding Engineering Foundation, should address Alfred D. Flinn, Secretary, 29 West 39th Street, New York.

PERSONAL MENTION

W. H. Moran has accepted a position with the Electriska Aktiebolaget Eck, Partille, Sweden, as general sales manager. He was formerly located in Helsingfors, Finland.

Laurence M. Cockaday is now technical editor of *Popular Radio* published in New York. He was previously with the Habirshaw Electric Cable Company, Yonkers, N. Y.

J. Elmer Housely has been appointed sales engineer of the Aluminum Company of America, with headquarters in Kansas City, Mo.

Charles F. Lloyd, formerly manager of the substation section of the Westinghouse Electric and Mfg. Company, East Pittsburgh, has been appointed manager of the electric division of the company.

Howard Monroe Raymond has been appointed president of the Armour Institute of Technology. Dr. Raymond has served as acting president of that Institute since the death of Dr. Frank W. Gunsaulus last year, and has also been dean of engineering since 1903.

Paul J. Kruesi has been appointed Acting Assistant Secretary of Commerce during the absence of C. H. Huston abroad. Mr. Kruesi has a number of business interests, being president and owner of the American Lava Company and the Southern Ferro-Alloys Company in Chattanooga, Tenn.

L. C. Bullington, who has been assistant to the manager of the power department of the Westinghouse Electric & Mfg.

Company, East Pittsburgh, has been made assistant manager and will have charge of the general work of the power department.

F. S. Hunting, who has for several years been connected with the General Electric Co. as general manager of its Ft. Wayne Works, has been appointed president and general manager of the Robbins & Myers Co., with factories at Springfield and Xenia, Ohio, and Brantford, Ont. Mr. Hunting has had 34 years' experience in the production and sale of small motors.

John C. Parker has terminated his connection with the University of Michigan, where he was professor of electrical engineering, and will be located with the Brooklyn Edison Company, Brooklyn, N. Y., as electrical engineer. Prof. Parker has had a great deal of active engineering experience as well as teaching work. He is a vice-president of the Institute.

Calvin P. Eldred, professor of electrical engineering at Rensselaer Polytechnic Institute, has resigned to become connected with the John A. Manning Paper Company and the Manning Abrasive Company of Green Island, N Y. Prof. Eldred was previously head of the electrical engineering department at the Georgia School of Technology.

M. M. Goldenstein of Milwaukee has become connected with the Chicago office of the Sprague Electric Works as sales engineer. Mr. Goldenstein was for many years chief engineer of the printing equipment department of the Cutler-Hammer Manufacturing Company, and is regarded as one of the leading authorities in the country on newspaper press control. He has taken out a number of patents on his inventions in this field.

Harold V. Bozell has been appointed an editor of the *Electrical World* in executive charge of the paper. Mr. Bozell has been for the past two years coeditor of the *Electric Railway Journal* and more recently editor of the new McGraw-Hill publication *Bus Transportation*, and has been acting as managing editor of the *Electrical World* for the past few months. He will retain his connection with the other two papers as consulting editor.

D. H. Braymer, who has been coeditor of *Electrical World*, is now devoting all of his time to the *Electrical Review and Industrial Engineer*, formerly the *Electrical Review*, which was purchased by the McGraw-Hill Company last winter. Mr. Braymer has been made publishing director as well as editorial director of the paper, with headquarters in Chicago. He is discontinuing his official position as editor of *Electrical World* on July 1.

E. W. P. Smith has been appointed chief engineer of the Lincoln Electric Company, Cleveland, O. Mr. Smith has been electrical engineer with this company for the past four years. Previous to that time he had ten years varied engineering experience, including a term as city electrician of Cleveland, during which the entire electrical code was revised and brought up to modern practise requirements. Mr. Smith is a past-chairman of the Cleveland Section of the Institute.

M. G. Lloyd, chief of the Safety Section of the U. S. Bureau of Standards, Washington, has been elected to the Board of directors of the Eyesight Conservation Council of America with headquarters in New York. He will take part in a national movement for eye conservation which has been started by the Council, and which it is planned, will be carried into the schools and industries of the nation. Dr. Lloyd has played a leading part in the preparation of the National Safety Code for the protection of heads and eyes of industrial workers

Alfred D. Flinn, secretary of the Engineering Foundation and chairman of the Division of Engineering of the National Research Council, is on a tour of several weeks to the Pacific Coast. His itinerary, which began at Salt Lake City on June 26, will include Los Angeles, San Francisco, Sacramento, Riverside and Davis, Cal.; Portland, Ore.; Seattle and Bellingham, Wash.; Vancouver, B. C.; Prince Rupert, Jasper Park, Alta.; Winnipeg, Duluth, Minneapolis and Chicago. Mr. Flinn goes on behalf of organized research to enlist the aid of engineers of the far West in a nationwide plan of industrial research in which the Foundation, the Council, Government departments and the industries will link their efforts. A big research highway program and the movement to drive the shipworm from American ports, in which it has caused billions of dollars worth of damage, are among the projects which he will explain.

Obituary

Hans J. Norregaard, who became an Associate of the Institute in 1920, died in Europe March 30, 1922. Mr. Norregaard had worked in the U. S. with the Westinghouse Electric & Mfg. Co., the General Electric Co., Stone & Webster, of Boston, the Interborough Rapid Transit Co., New York City, and the New York Edison Co. He was born in Christiana, Norway, in 1897, and attended the Hortens Engineering College, Norway. He also spent one year in the Massachusetts Institute of Technology.

Thomas F. Judge, superintendent of the Anglo-Newfoundland Development Co., Ltd., Grand Falls, Newfoundland, died suddenly on May 12, 1922. Mr. Judge was born in Biddeford, Me., in 1877, and was graduated from the electrical engineering course of the University of Maine in 1900. He then did electric designing and installation work for a number of years with various companies in the east, including the states of Maine, New York, Ohio and North Carolina. Going to Grand Falls in 1909, he later became superintendent of the Anglo-Newfoundland Development Co., remaining there until the time of his death. Mr. Judge joined the Institute in 1908.

John Martin, head of the alternating-current designing department of the British Thomson-Houston Co., Rugby, died on May 23, 1922, at his residence in Rugby. Mr. Martin was born at Little Arduthie in 1878, the son of the late Mr. James Martin of Farrochie, Stonehaven, Kincardineshire, and was educated at Stonehaven and Aberdeen, studying engineering afterwards at Glasgow University where he took the degree of B. Sc. On leaving the University he joined the Works of the British Electrical Plant Co. Alloa, as a pupil, and later entered the British Thomson-Houston Works at Rugby in 1903. Shortly after joining these works he entered the designing office and became associated with the design of induction motors and allied apparatus. From 1914 until the time of his death he was in charge of this work. Mr. Martin was of the best, Scottish character, holding high ideals and using the full force of his character to uphold these ideals. Although of a retiring disposition his strong character endeared him to a very wide circle of friends. While leading a very strenuous life, he managed to devote a considerable time to his garden, and was also a keen golfer and tennis player. He was an Associate Member of the British Institution of Electrical Engineers, and an Associate of the A. I. E. E., which he joined in 1907.

M. Yokura, Engineer Rear-Admiral in the Imperial Japanese Navy, died in Japan on June 23, 1922, according to a cable dispatch received by the Naval Inspector's office in New York. Rear-Admiral Yokura was a Fellow of the A. I. E. E. A graduate of the Imperial Japanese Naval Engineering College, he entered the Japanese Navy in 1901. After several years of sea service as engineer-lieutenant, he taught in the Engineering College for a year, and then for three years was a post-graduate student in the electrical engineering designing course of the Higher Naval College. Completing this course in 1909, he was placed in charge of the electrical workshop of the Yokosuka Naval Dock Yard, and promoted to engineer-commander. From that time on he received promotions and appointments to posts of responsibility, having been in charge for three years of the electrical engineering branch of the Imperial Japanese Naval Inspectors' office in England, and from 1917 to 1919 in charge of the I. J. N. Inspectors' office in the United States. In 1919 he was made chief of the Electrical Engineering Bureau

of the Japanese Navy, in charge of all electrical matters. He left New York for Japan in 1921. Rear-Admiral Yokura was born in Tokyo, December 1, 1877. He was one of the directors of Nippon Denki Gakukai (Electrical Engineering Society of Japan). He became an Associate of the A. I. E. E. in 1917 and was transferred to the grade of Fellow early in 1921.

William Baldwin Vansize, a Life-Member of the Institute, died at his home in Brooklyn, N. Y., on June 1, 1922. Mr. Vansize was a patent attorney, specializing in legal work for telephone, telegraph and electrical companies. He had been connected as patent expert with such companies as the Western Union, the American Bell Telephone Company, the General Electric Company, the Commercial Cable Company, the Edison Company, the American Marconi Company and the Radio Corporation. He was born in Utica, N. Y., in 1853, and in his youth worked as telegraph operator for the Western Union. In 1879 he was graduated from the Albany Law School and was admitted to the bar in the same year. He joined the A. I. E. E. in 1884, shortly after it was founded and from 1894 to 1897 was a manager of the Institute.

George Gray Ward, vice-president and general manager of the Commercial Cable Co., New York, died at his home in New York City on June 15, 1922, after several months of failing health. Mr. Ward was born December 30, 1844, at Great Hadham, Hertfordshire, England. He was interested in telegraphy as a child and entered the employ of the Electric Telegraph Company after finishing a general education at private and public schools. In 1865 he went to Alexandria in the telegraph service of the Egyptian government, sticking to his post through the cholera epidemic of that year, and in 1869 joined the French Atlantic Cable Co. After five years he returned to England on account of ill health, but soon took up work again, coming to this country as superintendent of the Direct United States Cable Company. Ten years later, in 1884, Mr. Ward became general manager of the Commercial Cable Company at the invitation of the late John W. Mackay who had just organized the company. In 1890 he was elected vice-president holding both positions until the time of his death. It was largely through Mr. Ward's efforts that transoceanic cable service has been brought to its present degree of efficiency. In addition to his other duties, Mr. Ward was a director of the Commercial Company of Cuba, Commercial Pacific Cable Company, the Mackay Companies, the National Surety Company, Postal Telegraph Cable Company, U. S. and Hayti Telegraph & Cable Co., and the U. S. Mortgage & Trust Co. He was president of the St. George's Society of New York in 1899 and 1900, was a manager of St. Luke's hospital, and a member of various clubs and associations. He was a Life Member of the Institute which he joined in 1908.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (MAY 1-31, 1922)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Annals of the American Academy of Political and Social Science, May 1922. 315 pp., 9 x 6 in., paper. $1.00.

Contents:—The Significance of the Ethical Codes for the Professions.—The Ethical Codes of Lawyers.—The Ethics of the Medical Profession.—The Ethical Codes of the Engineers.—The Ethics of the Architects.—Ethical Standards for Teachers, Librarians, Ministers and Social Workers.—Ethical Standards for Journalists.—The Ethical Code of Accountants.—Ethics in Business.—Supplement: Modern China and her Present Day Problems.

The American Academy of Political and Social Science has done a great service to all the professions by bringing together for the first time in one collection the concepts of what constitutes the attainment of the ideals of a profession, in distinction from those of a vocation.

As respects the Engineering Societies, the authors representing the leading societies have, by long contact in their respective organizations, not only themselves advanced the high ideals of their professions but have contributed personally, both in conference and in committee to the adoption of those principles which they describe in their several articles. Every engineer wishing to stand for the advancement of his profession should read this entire issue of the Annals.

Directive Wireless Telegraphy.

By L. H. Walter. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1921. (Pitman's technical primers.) 124 pp., illus., diagrs., 6 x 4 in., cloth. $.85.

A short-connected account of the principles of the method of wireless direction finding, together with the essentials of directive wireless telegraphy upon which it is based. Although small, the volume aims at giving an outline of all the information available. It is intended for those who are about to use the directive finder and for those who are interested in directive wireless telegraphy. A bibliography is given as a guide for those who desire to study the theory fully.

Die Drahtlose Telegraphie und Telephonie.

Von P. Lertes. Dresden und Liepzig, Theodor Steinkopff, 1922 (Wisenschaftliche forschungsberichte.) 152 pp., diagrs., 9 x 6 in., paper. 78 M.

The need for concise summaries of current literature on scientific subjects is felt by all investigators, and particularly at present by German scientists, most of whom were unable, during the war, to keep in touch with developments in their respective fields of study. The present volume is one of a series prepared to meet this need, by providing reviews of the advances after 1914 along various lines, prepared by competent students of each subject.

This review of advances in radio communication covers theory and the various parts of sending and receiving apparatus. The literature from 1914 to 1921 has been examined. Bibliographies are given for each section.

PAPERS ON CURRENT TRANSFORMERS.

By H. W. Price and C. Kent Duff. University of Toronto Press, 1921. (University of Toronto School of Engineering Research. Bulletin No. 2, Section No. 4.) 65 pp., illus., diagrs., 9 x 6 in. Free.

The five papers contained in this bulletin are the electrical studies for the year 1921 at the University of Toronto School of Engineering Research. They have to do with investigations of the effects of magnetic leakage, a method of measuring ratio and phase angle, through-type portable transformers and with minimizing errors by means of shunts. In view of present interest in the design of current transformers, these papers will be of value to designers. Little is available in print upon the subjects here discussed.

STEAM POWER PLANT AUXILIARIES AND ACCESSORIES.

Terrell Croft, editor. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 447 pp., diagrs., illus., 8 x 6 in., cloth. $3.00.

This book is intended to give data that will assist the power plant engineer to select proper auxiliary equipment and install, operate and maintain it so that preventable losses will be kept as low as possible and power will be generated at the least cost. The subjects treated include pumps, boiler-feeding apparatus, feed-water heaters, economizers, condensers, cooling ponds and towers, steam piping, steam separators and steam traps. The treatment is simple, non-mathematical and descriptive.

DIE ELEKTROTECHNIK UND DIE ELEKTROMOTRISCHEN ANTRIEBE

Von Wilhelm Lehmann. Berlin, Julius Springer, 1922. 451 pp., illus., diagrs., 9 x 6 in., cloth. $2.35.

The problems that confront the greater number of electrical engineers today are not, the author believes, connected with the construction of electrical machinery nor the generation of electricity, but with the industrial use of electrical energy. His book therefore is chiefly devoted to discussing types of electrical machines and their suitability for various purposes. Direct-current, alternating-current and induction generators and motors, transformers, the transmission and distribution of electric power, and its use for lighting, and power purposes are considered. One section is devoted to electric driving in the more important industries.

DIENST VOOR WATERKRACHT EN ELECTRICITEIT IN NEDERLANDSCH-INDIE.

Derde jaarverslag, 1920. Bandoeng, 1921. 71 pp., plates, maps, tables, 10 x 7 in., boards.

The annual report for 1920 of the Hydroelectric Service of the government of the Dutch East Indies contains a brief account of its activities in examining and developing the water powers of Java, Sumatra, Celebes and the smaller islands. Statistical tables, maps and graphic charts give much detailed information, and the report is well illustrated by photographs.

DESIGN AND CONSTRUCTION OF DAMS.

By Edward Wegmann. Seventh edition. N. Y., John Wiley & Sons, Inc., 1922. 555 pp., plates, diagrs., 12 x 9 in., cloth. $10.00.

The changes in this edition consist chiefly of added matter, amounting to about fifty pages of text and five plates. A new chapter has been inserted upon crest-gates and siphon spillways, additional descriptions of recent dams are given and the bibliography has been extended. A full description of the construction of the Kensico dam is given and the movable dams of the New York State barge canal are described.

DICTIONARY OF APPLIED CHEMISTRY.

By Sir Edward Thorpe. Vol. 3. Revised and enlarged edition. N. Y., Longmans, Green and Co., 1922. 735 pp., illus., 9 x 6 in., cloth. $20.00.

The third volume contains an important article, 98 pages long, on explosives, by G. H. Perry; one on glass by W. E. S Turner; on water-gas, by Alwyn Meade; on iron by Thomas Turner. Dr. William a Bone contributes an article on fuel, Dr. Arthur Harden one on fermentation. The articles on fire extinction and prevention, and on air gas and oil gas are by Vivian B. Lewes Dr. Julius Lewkowitch is responsible for a number of articles on oils, fat and waxes.

CHEMISTRY OF THE NON-BENZENOID HYDROCARBONS.

By Benjamin T. Brooks. First edition. N. Y., Chemical Catalog Co., Inc., 1922. 612 pp., 9 x 6 in., cloth. $7.00.

The compounds considered in this book include such industrially important substances as petroleum, rubber, turpentine, camphor and the essential oils. Dr. Brooks presents a systematic description of the chemistry of the non-benzenoid hydrocarbons, in which is included both matter of only theoretical interest and descriptions of industrial processes. The volume is a useful review of a field usually given a secondary position in treatises on organic chemistry. Ample references to the previous literature are included.

INORGANIC CHEMISTRY.

By T. Martin Lowry. Lond., Macmillan and Co., Ltd., 1922. 943 pp., illus., diagrs., 9 x 6 in., cloth. $9.00. (Gift of The Macmillan Co., N. Y.)

A large textbook which is intended to bridge the gap between the elementary class book and the larger reference treatises. Presents the subject in a modern way giving full weight to the influence of physical chemistry upon the subject.

The earlier historical and introductory chapters treat of states of matter salts, acids, alkalies, combustion, chemical combination, the atomic theory, crystallization, etc. The systematic part of the book describes the elements and their compounds. Equilibrium diagrams have been used freely and important industrial operations described.

PROTEINS AND THE THEORY OF COLLOIDAL BEHAVIOR.

By Jacques Loeb. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 292 pp., tables, charts, 9 x 6 in., cloth. $3.00.

Colloid chemistry has been developed on the assumption that the ultimate unit in colloidal solutions is not the isolated molecule or ion but an aggregate of molecules or ions. Since it seemed improbable that such aggregates could combine in stoichiometrical proportions with acid, alkalies or salts, the conclusion was drawn that electrolytes were absorbed on the surface of colloidal particles according to a purely empirical formula.

Dr. Loeb's investigations have shown that this last conclusion is based on a methodical error, that proteins combine with acids and alkalies according to the stoichiometrical laws of chemistry and that the chemistry of proteins does not differ from the chemistry of crystalloids. This book furnishes the proof of his conclusions and outlines a mathematical and quantitative theory of colloid behavior.

FLUIDITY AND PLASTICITY.

By Eugene C. Bingham. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 440 pp., tables, diagrs., 8 x 6 in., cloth. $4.00.

Dr. Bingham's book is a careful study of our knowledge concerning the flow of gases, liquids and solids, and of the theories that have been advanced by different investigators. Part one discusses viscometry and the viscometer. Part two treats of viscosity, fluidity and plasticity, and includes chapters on lubrication and on further applications of the viscometric method. The author offers a theory of flow in general, the first to be published. An extensive bibliography is included.

ISOTOPES.

By F. W. Aston. Lond., Edward Arnold & Co., 1922. 152 pp., plates, diagrs., 9 x 6 in., cloth. $3.00. (Gift of Longmans, Green & Co.)

In clear readable style, Dr. Aston gives an adequate exposition of the phenomena of isotopic elements. The book gives an exact account of the discovery of isotopes, of the methods used to detect them and of present theories in explanation of them. Particular attention is paid to the author's mass-spectograph and the work done with it upon various elements.

DICTIONARY OF APPLIED PHYSICS. VOL. 1.

Edited by Sir Richard Glazebrook. Lond., Macmillan and Co., Ltd., 1922. 1067 pp., illus., diagrs., 9 x 6 in., cloth. $15.00.

The first volume of an important work of reference in which will be summarized the present state of our knowledge of physics as applied to matters of engineering and manufacturing. Each volume will cover one branch of the science and be practically complete within itself. In preparing the book, Sir Richard Glazebrook has had the help of many of the leading physicists, who have contributed articles on their specialties. The work will consist of five volumes.

The present volume covers Mechanics, Engineering and Heat. It contains extensive reviews upon Steam and Internal Combustion Engines, Hydraulics, Calorimetry and Thermometry, Lubrication, Determination of Elastic Constants, Thermodynamics, Friction, Steam Turbines, Ship Resistance, Strength of Structures and Dynamometers. Bibliographies are given.

COURS DE MECANIQUE APPLIQUEE.

By Marcel Lamotte. Paris, Gauthier-Villars et Cie, 1922. 282 pp., diagrs., 10 x 6 in., paper. 25 fr.

Professor Lamotte feels that most text-books of applied mechanics require more extensive knowledge than the usual stu-

dent possesses and are unnecessarily difficult. He has prepared this book, not to replace the more elaborate treatises on the subject, but to prepare the student for them, so that he may derive the most profit from their perusal. This is accomplished by presenting in the simplest form possible, some of the questions that affect the applications of mechanics. He is less concerned in establishing general theories than in showing, by examples, how practical problems may be solved.

COAL MANUAL FOR SALESMEN, BUYERS AND USERS.

By F. R. Wadleigh. Cincinnati, O., National Coal Mining News, 1921. 184 pp., 6 x 5 in., cloth. $2.50.

A book of pocket size intended to give accurate elementary knowledge regarding the origin, structure, chemistry and uses of coal. It is intended for salesmen and users of coal who wish information upon methods of purchasing, transporting and testing coal and coke, on the requirements of various users, and on proper methods of using fuel.

COAL MINING COSTS.

By A. T. Shurick. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 515 pp., diagrs., tables, 9 x 6 in., cloth. $5.00.

Although books on costs exists for all the other important branches, this is the first to treat of coal mining costs. The author has restricted his inquiry to underground costs, covering mining, shaft sinking, haulage, timbering and various miscellaneous items.

The treatment has been made as thorough and specific as possible. By giving the date when each piece of work was done and including a table showing all the wage scales in the Central Competitive District since 1898, it has been made a simple matter to estimate the cost in terms of present wage scales.

FUEL AND REFRACTORY MATERIALS.

By A. Humboldt Sexton. New edition, revised by W. B. Davidson. N. Y., D. Van Nostrand Co., 1921. 382 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

No important alterations have been made in the original text of this well-known work, but minor corrections have been made throughout. The chapters on liquid and gaseous fuels have been modified and enlarged, and the chapter on by-products has been rewritten. The chapters on fuel testing and refractories have been modernized and enlarged.

The book discusses the important industrial fuels, metallurgical furnaces, pyrometry, calorimetry, fuel testing and the refractory materials used for furnaces and crucibles.

CYANIDING GOLD AND SILVER ORES.

By H. Forbes Julian and Edgar Smart. Third edition, revised and enlarged. Lond., Charles Griffin and Co., Ltd.; Phila., J. B. Lippincott Co., 1921. 417 pp., diagrs., tables, 9 x 6 in., cloth. $12.50.

The second edition of this well-known treatise appeared in 1907. Work upon the present edition began in 1914, interrupted by the death of Mr. Smart and by the Great War, but finally completed by A. W. Allen.

Much new material dealing with recent modifications in the theory and operation has been added and the chapters have been rearranged to secure greater uniformity. The principal additions are in connection with colloidity and absorption; the theory of gold precipitation on charcoal; milling in cyanide solution, flotation and cyanidation; zinc-box practise; deoxidizing solutions; counter-current decantation; aluminum, sodium sulfid and charcoal precipitation; agitation slime-settlement and filtration equipment.

DETERMINATION OF SULFUR IN IRON AND STEEL; with a bibliography, 1797-1920.

By H. B. Pulsifer. Easton Pa., Chemical Publishing Co., 1922. 160 pp., illus., 9 x 6 in., cloth. $2.50.

Although the determination of sulfur is one of the fundamental control analyses in ascertaining the quality of iron and steel, and is in regular daily use in all laboratories, there is still a lack of suitable accuracy and an unflattering absence of agreement between analysis which calls for study of the methods in use. The present book is a review of present knowledge concerning the sulfids that occur in iron and steel, the methods of analysis, the results obtained with them and the precision of these results. It is intended to provide a basis for research. The bibliography (pp. 53-155) covers the literature from the beginnings of wet analytical chemistry and is fully annotated.

THERMAL STRESSES IN CHILLED IRON CAR WHEELS.

By G. K. Burgess and R. W. Woodward. Wash., Government Printing Office, 1922. (Technologic papers of the Bureau of Standards, No. 209.) 34 pp., plates, diagrs., 10 x 7 in., paper. $.05.

Describes a method for testing car wheels under conditions nearly like those encountered in descending long grades, and gives the results obtained from a series of tests. Twenty-eight wheels of varying weight and design were tested, sixteen of which cracked in the plate. The tests suggest the possibility of improving the design of these wheels.

STEEL FOUNDRY.

By John Howe Hall. Second edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 334 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00

Mr. Hall's object has been to set forth the metallurgy of the steel foundry from the point of view of the engineer interested in prescribing the cheapest means of producing objects of sufficient excellence for the purposes for which they are intended. His book considers the classes of steel castings in demand today and their characteristics from a manufacturing point of view; the types of steel making processes in use and their characteristics that govern the selection of one or another for making the sort of castings desired; and shop procedure in the light of its influence on quality and cost.

The revision has introduced new data on electric furnace practise, on molding sands, heat treatment and other phases of foundry practise.

MANUFACTURE OF PULP AND PAPER. VOL. 3.

First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. Illus., diagrs., 9 x 6 in., cloth. $5.00.

This is the third volume of the course of instruction in pulp and paper manufacture prepared by the pulp and paper industry of North America for those actively engaged in the industry. Previous volumes have been devoted to the elementary scientific knowledge—physical, chemical and mathematical—needed by the paper maker, the present volume takes up the actual manufacturing processes. It is, the editor announces, the first work in English dealing solely and comprehensively with wood pulp manufacture.

The various sections have been prepared by specialists. They describe the properties of pulpwood, its preparation, the manufacture of mechanical sulphite, soda and sulphate pulps, and the treatment, refining, testing and bleaching of pulp.

PRACTICAL TANNING.

By Allen Rogers. N. Y., Henry Carey Baird & Co., Inc., 1922. 699 pp., illus., port., 9 x 6 in., cloth. $10.00.

As Dr. Rogers has written for the practical tanner, his book gives prominence to the methods used for the actual production of leather, although the scientific principles upon which these methods are based are also stated, in simple language.

In addition to the common standard methods of tanning, a number of unusual processes are given, as well as descriptions of some of the substitutes for leather. The book is based on Flemming's "Practical Tanning," with the addition of the results of the author's personal experience.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Clyde B. Andrews, c/o Mrs. G. F. McKay, Box 35, Ben Lomond, Calif.
2.—Eugene A. Baerer, Box 253, Kenvil, N. J.
3.—Ricardo S. Bravo, Jr., 621 So. Flores St., San Antonio, Texas.
4.—Waldo C. Cole, 410 Jills Bldg., El Paso, Texas.
5.—E. J. Condon, Jr., Minn. Elec. Lt. & Pr. Co., Elks Bldg., Bemidji, Minn.
6.—O. A. Darnell, 409 East 5th St., Los Angeles, Calif.
7.—John F. Donohue, 45 2nd St., Newark, N. J.
8.—Edward F. Doyle, c/o Nat'l. Conduit & Cable Co., Hastings-on-Hudson, N. Y.
9.—M. V. Eardley, P. O. Box 664, Long Beach, Calif.
10.—Earl V. Edkins, 5827 Trinity Place, W. Philadelphia, Pa.
11.—E. W. Erikson, 214 Univ. Club Bldg., St. Louis, Mo.

12.—J. Allen Fitz, 19 Ft. Green Place, Brooklyn, N. Y.
13.—John F. Hasler, 47 Day St., Ansonia, Conn.
14.—Frank Hempton, P. O. Box 431, Gallup, New Mexico.
15.—Arthur S. Howard, 2735 So. Alder St., Philadelphia, Pa.
16.—Carl Irving, Box 675, Porterville, Calif.
17.—J. M. Kite, Guaranty Co. of N. Y., 140 Broadway, New York City.
18.—Leonard Knowles, 411 So. 56th St., Philadelphia, Pa.
19.—Gody Krusy, 16 Elizabeth Ave., Newark, N. J.
20.—Robert J. Latorre, International Paper Co., Jay, Maine.
21.—Wen Siang Lu, Y. M. C. A., Lynn, Mass.
22.—Thos. H. McCauley, c/o New Brunswick Pr. Co., St. Johns, N. B.
23.—H. F. Pippenger, 4647 Kenmore Ave., Chicago, Ill.
24.—Walter Scott, 424 Rockingham St., Toledo, Ohio.
25.—R. W. Seem, 633 W. 74th St., Los Angeles, Calif.
26.—J. Hubert Shahan, 527 Morris Ave., Elizabeth, N. J.
27.—F. W. Smith, 500 Tidd St., Wilkinsburg, Pa.
28.—Theo. V. Tillinghast, c/o Plano Toy Co., Plano, Ill.
29.—C. H. Underwood, Room 220, Rt. Equipment Dept., Gen. Elec. Co., Schenectady, N. Y.
30.—Louis H. Wessels, 105 Union St., Jersey City, N. J.

Past Section and Branch Meetings

PAST SECTION MEETINGS

Akron.—April 26, 1922, Engineering Society of Akron Rooms. Subject: "Contribution of Electrical Science to the Religious Thought of This Generation." Speaker: Dr. Lloyd C. Douglas, First Congregational Church of Akron. Attendance 30.

May 24, 1922, Engineering Society of Akron Rooms. Election of officers as follows: Chairman, H. C. Henton; secretary-Treasurer, A. P. Regal; Executive Committee, Messrs. M. Berthold and T. J. Newman. General Subject: "What My Experience Has Taught Me to Avoid." Speakers: Messrs. R. R. Jones, V. W. Shear, B. S. Dales, E. A. Kemmler and A. P. Harpster. Attendance 23.

Atlanta.—May 4, 1922, Georgia Tech. Y. M. C. A. Auditorium. Mr. W. E. Bowler, of the Western Electric Company, exhibited six reels of films showing the harvesting of Western Red Cedar Poles in the Northwestern Forests, and a two-reel film showing the manufacture of fir cross-arms. Mr. Bowler also gave a short talk on cross-arm manufacture. Attendance 30.

Baltimore.—May 19, 1922, Engineers' Club. Election of officers as follows: Chairman, Professor W. B. Kouwenhoven; vice-chairman, Vern E. Alden; secretary, Frank T. Leilich; Executive Committee, Messrs. Allner, Gerhardt, Faught, Walden and Davis. Subject: "The Application of Electricity to the Steel Industry." Speaker: Mr. R. B. Gerhardt, Electrical Superintendent of the Sparrows Point Plant of the Bethlehem Steel Company. Attendance 50.

Chicago.—May 22, 1922. Election of officers as follows: Chairman, F. E. Goodnow; vice-chairman, Charles H. Jones; secretary, J. E. Kearns; Executive Committee, Messrs. Fowler, Bangs and Hail. Subjects: "The Use of Purchased Electrical Power in Coal Mines" (presented from the standpoint of the power producer), by Mr. J. Paul Clayton, vice-president, Central Illinois Public Service Company; "The Use of Purcha (presented from the standpoint of the coal operator) by Mr. W. C. Adams, electrical engineer, Allen & Garcia; "Central Station Power for Coal Mines," by Mr. J. C. Damon, West Penn Power Company. Attendance 100.

Cincinnati.—May 11, 1922, Assembly Hall, Union Gas & Electric Company. Subject: "Electric Furnaces" (illustrated by lantern slides). Speaker: Mr. J. L. Cawthon, Jr., of the W. E. Moore Company, Pittsburgh, Pa. Attendance 28.

June 8, 1922, Maketewah Country Club. Annual Meeting. Election of officers as follows: Chairman, Professor A. M. Wilson; secretary-treasurer, C. G. Eichelberger; Executive Committee, Messrs. James, Reiff, Healey, Willey and Schoepf. Attendance 28.

Columbus.—May 26, 1922, Rooms of the Engineers Club of Columbus. Business meeting and election of officers as follows: Chairman, Professor F. C. Caldwell; secretary-treasurer, F. C. Nesbitt; Executive Committee, Messrs. Norton, Fitz, Janowitz, Crammes. Attendance 17.

Connecticut.—May 23, 1922, Hotel Taft, New Haven, Conn. The meeting was preceded by a dinner. Speakers: Mr. Henry L. Doherty, president of the Cities Service Company, spoke on the 3-part gas and electric rate which he introduced in 1900, of the need for equity in rates rather than mere simplicity, and of the value of complete publicity of utility affairs; Mr. Calvert Townley, assistant to the president of the Westinghouse Electric & Manufacturing Company, dealt with the obstacles other than financial to extensive electrification of the steam railroads; President James Rowland Angell, of Yale University, in a few well chosen words pointed out the completely complementary relation between science teaching and research and the application of science to industry. Following the addresses the following election of officers was announced: Chairman, Edward H. Everit; secretary-treasurer, A. E. Knowlton; Executive Committee, Messrs. Ferguson, Leland, Moore, Catlin and Shepard. Attendance 100.

Detroit-Ann Arbor.—May 11, 1922. Subject: "The Ventilation of Power Plants" (illustrated by lantern slides). Speaker: Professor C. F. Hirshfeld. Attendance 80.

Erie.—May 16, 1922, Public Library. Election of officers as follows: Chairman, W. J. Seibert; secretary, M. W. Metzner; Executive Committee, Messrs. Burke, Lemp, Reynolds and Schum. Subject: "Cranes and Other Hoisting Equipment." Speaker: Mr. P. R. Urich. Attendance 25.

Fort Wayne.—May 18, 1922, Dormitory of the Wayne Knitting Mills. Following an inspection trip through the silk mill, a short business meeting was held, and announcement made of the election of the following officers: Chairman, S. W. Greenland; vice-chairman, Dr. C. C. Grandy; secretary, A. B. Campbell; assistant secretary, L. C. Yapp; Executive Committee, Messrs. Hockett and Staehle. Reports were also presented from the Entertainment Committee, Membership Committee, and from the Secretary covering the year's expenditures of the Section. Refreshments were served. Attendance 50.

Kansas City.—May 26, 1922, University Club. Subject: "Automatic Printing Telegraph." Speaker: Mr. J. Tyler, wire chief, Western Union Telegraph Company, Kansas City. Complete sending and receiving apparatus was installed and its operation demonstrated at the meeting. Attendance 18.

Los Angeles.—May 12, 1922, Assembly Room, Chamber of Commerce. Subject: "Some Recent Developments in Telephone Engineering." Speaker: Mr. D. I. Cone, of the Pacific Telephone & Telegraph Company of San Francisco. Attendance 95.

Madison.—May 8, 1922, Auditorium Engineering Building, University of Wisconsin. Joint meeting with Engineering College, University of Wisconsin. Subject: "The Human Voice and Its Electrical Transmission." Speaker: Mr. John Mills, of the Western Electric Company, New York City. Attendance 250.

New York.—A joint meeting of the N. Y. Section of the A. I. E. E. and the Institute of Radio Engineers was held on the evening of Tuesday June 20, 1922 at the Engineering Societies Building, 33 West 39th St., N. Y. Senator Marconi pre-

sented a paper on "Radio Telegraphy" before an audience of over 1100 engineers. Directly following his talk, the Institute of Radio Engineers presented him with the Institute of Radio Engineers Medal of Honor awarded by the Board of Direction for pioneer work in the radio field, leading substantially to its development. Senator Marconi demonstrated by means of apparatus set up on the stage, the possibility of directing wireless waves in any direction desired. For this demonstration he utilized a wave length of one meter. Other speakers of the evening were Dr. Pupin and Major Armstrong. (An abstract of Senator Marconi's paper is given elsewhere in this issue. The complete paper will be published in a forthcoming issue of the JOURNAL.)

Portland.—June 2, 1922, Multnomah Hotel. Annual social and business meeting. Radio concert, informal dance and buffet luncheon. Attendance 82.

Rochester.—May 26, 1922, Rochester Engineering Society Rooms. Business meeting and election of officers as follows: Chairman, G. A. Scoville; secretary, E. A. Roeser; Executive Committee, Messrs. Bodler, Ward and Stetler. Subject: "Automatic Train Control and Signaling." Speaker: Mr. W. K. Howe, chief engineer of the General Railway Signal Company. Attendance 62.

St. Louis.—May 24, 1922, Engineers' Club. Subject: "Automatic Station" (Illustrated by slides). Speaker: Mr. W. C. Place, engineer on automatic hydroelectric stations for the General Electric Company at Chicago. Refreshments were served. Attendance 65.

San Francisco.—April 28, 1922, Engineers' Club. Subject: "Impressions Gained from a Recent Trip to Central and Northern Europe." Speaker: Mr. L. R. Jorgenson. Attendance 60.

May 26, 1922, Engineers' Club. Subjects: "Introduction—"Factors in the Operation of Long High-Voltage Lines which make Such Tests Necessary, Expected Benefits from Such Tests, etc." by Mr. J. P. Jollyman; "The Transient Crest Voltmeter" by Mr. F. E. Terman; "Results of Wave Form and Crest Voltage Tests" by Mr. R. Wilkins. Attendance 85.

Seattle.—April 19, 1922, Engineers' Club. Subject: Psychology in Industry." Speaker: Dr. E. R. Guthrie, Professor of Psychology, University of Washington. Attendance 94.

Spokane.—April 28, 1922, Davenport Hotel. Subject: "Snow Survey and Other Methods of Forecasting Water Supply." Speaker. Mr. J. B. Fisken. Attendance 36.

May 26, 1922, Davenport Hotel. Annual Dinner Meeting and Election of Officers as follows: Chairman, H. L. Melvin; vice-chairman, J. S. McNair; secretary-treasurer, E. R. Hannibal; Executive Committee, Messrs. Fisken, Henderson, Ball and Pospisil. Attendance 18.

May 31, 1922, Davenport Hotel. Subject: "The Hydraulic and Electrical Features of the New Spokane Upper Falls Development of the W. W. P. Co." Speakers: Messrs. L. J. Pospisil and H. L. Melvin. Attendance 21.

Syracuse.—May 12, 1922. Election of officers as follows: Chairman, Rich D. Whitney; secretary, Elmer E. Strong; Executive Committee, Messrs. Delong, Bundy, Elliott, Adams and Brown. Subject: "Electrification of the Chicago, Milwaukee & St. Paul Railroad." Speaker: Mr. E. B. Curry. Attendance 65.

Urbana.—June 9, 1922. Subject: "Recording of Sound on Motion Picture Films, and Its Application to Talking Moving Pictures." Speaker: Professor J. T. Tykociner. Attendance 60.

Utah.—May 26, 1922, Commercial Club. Election of officers as follows: Chairman, C. C. Pratt; secretary-treasurer, C. R. Higson; Executive Committee, Messrs. Miller, Kahn, Kahler, Shaver and Ashworth. Subject: "The Signal System at the Utah-Apex Mine." Speaker: Mr. A. R. Willson, of the Utah-Apex Mining Company. Refreshments were served. Attendance 65.

Vancouver.—May 5, 1922, Board of Trade. Subject: "The A-C Potentiometer." Speaker: Mr. J. Stott, superintendent of gas and electricity, inspection service, of the Canadian Government. Attendance 24.

Washington.—May 9, 1922, Cosmos Club. Election of officers as follows: Chairman, L. T. Blaisdell; vice-chairman, L. M. Evans; secretary-treasurer, Roland Whitehurst; Executive Committee, Messrs. Stabler and Hamilton. By courtesy of the Bureau of Mines, two moving pictures entitled "The Story of Abrasives" and "The Mexican Oil Fields" were shown. Attendance 40.

Worcester.—May 25, 1922, E. E. Building, W. P. I. Subject: "Superpower—An Answer to the National Power Policy" (illustrated by lantern slides). Speaker: Mr. W. S. Murray, Consulting Engineer, and Director of Superpower Survey. Attendance 55.

PAST BRANCH MEETINGS

University of Arizona.—May 11, 1922. Election of officers as follows: Chairman, R. A. MacDonald; secretary-treasurer, H. A. Hillman. Illustrated lecture on "Steam Turbines" was given by Mr. J. A. Knost, of the Westinghouse Electric & Manufacturing Company. Attendance 27.

Armour Ins itute of Technology.—May 19, 1922. Election of officers as follows: Chairman, L. E. Grube; secretary, H. M. Piety; treasurer, H. G. Love. Attendance 38.

Carnegie Institute of Technology.—June 1, 1922. Subject: "The Human Engineer." Speaker: Mr. E. C. Stone, of the Duquesne Light Company. Attendance 30.

June 7, 1922. Election of officers as follows: Chairman, William S. Andrews; vice-chairman, Herbert G. Kost; secretary, Walter J. Lyman; Treasurer, Edward L. Reilly. Attendance 60.

University of Cincinnati.—May 1, 1922. Subject: "From the Manufacturer to the Consumer." Speaker: Mr. Curran, district manager of the Western Electric Company. Attendance 51.

May 6, 1922, Hotel Alms. Annual Banquet. Col. T. Schoepf, Chief Engineer of the Cincinnati Traction Company, was the principal speaker; other toasts given by Professor Hoffmann, J. E. Doran, Andre Pingon and Ray Redman. Prize awards for best student papers during the year as follows: First prize, H. E. Deardorff; second prize, Donnan Israel; third prize, E. R. House. Attendance 118.

May 8, 1922. Subject: "Automatic Telephony." Speaker: Mr. G. A. Granel, district manager of the Automatic Telephone Company. Attendance 35.

University of Colorado.—May 25, 1922. Mr. L. J. Murray of the Chicago, Milwaukee & St. Paul Railway Company, gave a talk on the electrification of that road, accompanied by slides and motion pictures. Attendance 67.

Iowa State College.—May 17, 1922. Subjects: "Wireless Telegraphy," by Mr. Deal; "The Bell System," by Mr. Bell, of the Northwestern Bell Telephone Company, of Ames, Iowa. Attendance 70.

University of Iowa.—April 5, 1922. Subjects: "Home Electric Ideas;" "The Motion Picture Projector;' "Highway Illumination;" by Messrs. Owen, Smoke and Roebuck respectively. Attendance 29.

April 25, 19 2. Subject: "Aerial Photography." Speaker: Mr. Thomas Roche. Attendance 30.

May 10, 1922. Subjects: "The Senior Class Inspection Trip to Chicago and Milwaukee" by Messrs. Smith and Stohr; "The Development of Automobile Ignition" by Mr. Tilton. Attendance 28.

Kansas State College.—May 8, 1922. The evening was taken up by members of the senior class giving short talks. Attendance 40.

May 21, 1922. Short general talks by Professors Keoffler, Brenneman and Palmer, and by the seniors, as this is the last meeting for this school year. Attendance 48.

University of Kansas.—May 11, 1922. Joint meeting with local branch of A. S. M. E. Election of officers as follows: Chairman, Donald Eyer, vice-chairman, Arnold Covey; secretary-treasurer, William Anderson. Subject: "Installation of Kansas City's New Street and Park Lighting System." Speaker: Mr. A. E. Bettys, of the Kansas City Light and Power Company. Attendance 38.

Lehigh University.—May 16, 1922. The feature of the evening was a debate on the question "Resolved that Electrification of Trunk Line Railroads will be Advantageous from a Standpoint of Operation and Maintenance." Attendance 33.

Massachusetts Institute of Technology.—April 20, 1922. Mr. E. L. Bowles explained the principles and operation of radio telegraphy. Attendance 75.

May 23, 1922. Election of officers as follows: Chairman, E. J. Thimmie; vice-chairman, T. H. Carpenter; secretary, H. D. McKinnon; treasurer, P. A. Blackwell. Speakers: Messrs. V. Bush and E. Thompson. Attendance 35.

Michigan Agri ultural College.—May 18, 1922. Subjects: "Engineering at M. A. C." by H. H. Halliday; "The Oscillograph" (demonstrated), by C. Bersey. Remarks by Professors Sawyer and Cory. Attendance 45.

University of Michigan.—April 26, 1922. Subject: "Intimate Details of the Construction and Installation of the Transcontinental Line of the Chicago, Milwaukee and St. Paul Railroad" (illustrated). Speaker: Mr. J. A. Anderson, superintendent of the locomotive shops of the Chicago, Milwaukee & St. Paul Railroad. Attendance 175.

May 20, 1922. Inspection trip to Detroit, visiting the Connors Creek Plant of the Detroit Edison Company, and the Michigan State Telephone Company. Attendance 41.

University of Minnesota.—May 31, 1922. Election of officers as follows: Chairman, Roy H. Olson; secretary, Clifford L. Sampson; treasurer, Robert H. Tunnel. Attendance 25.

University of North Carolina.—May 18, 1922. Subjects: "The Trolley Bus" by C. U. Smith; "The Psychology of Advertising" by J. R. Purser, Jr. Attendance 32.

May 31, 1922. Election of offic rs as follows: Chairman, W. C. Moore; vice-chairman, T. B. Jaccoks, Jr.; secretary, R. H. Jackson; treasurer, J. B. London. Attendance 34.

University of North Dakota.—May 1, 1922. Subject: "The Elimination of Waste in Industry." Speaker: Professor G. B. Wharen. The following moving picture films were shown: "Westinghouse Works" (scenes at E. Pittsburgh), "Schenectady Works" and "Pittsfield Works" of the General Electric Company. Attendance 28.

May 15, 1922. Election of officers as follows: Chairman, C. W. Randall; vice-chairman, Albert Cook; local secretary, Professor D. R. Jenkins; student secretary, Byron Hill; Executive Committee, Messrs. Erickson and Rudiselle. Attendance 17.

University of Oklahoma.—May 18, 1922. Election of officers as follows: Chairman, Cecil Rouch; vice-chairman, J. A. Diffendaffer; secretary, R. E. Thornton; treasurer, W. H. Reilly. A motion picture on "Dry Cell Battery Construction" was shown. Attendance 25.

Oregon State College.—May 10, 1922. Subject: "Principles of Rate Making." Speaker: Mr. C. J. Green. Attendance 29.

University of Pennsylvania.—May 18, 1922. Election of officers as follows: Chairman, Otto W. Manz, Jr.; vice-chairman, Justin J. Hanow; secretary, Arthur R. Horner; treasurer, John R. Sabina. Attendance 20.

Purdue University.—May 9, 1922. Mr. Harding, of Nordyke & Marmon Company, Indianapolis, gave tear-down and build-up demonstration of Marmon motor, which took fifty-four minutes. Mr. Wellington, of the Studebaker Corporation, explained six reels of film on the "Manufacture of Studebaker Light Six Cars." Attendance 315.

May 16, 1922. Election of officers as follows: Chairman, J. F. Welch; vice-chairman, J. J. Vichules; secretary, O. T. McIlvaine; treasurer, W. G. Modlin. Subject: "Public Utilities and How They Are Met Face to Face." Speaker: Mr. A. J. Rowland, of Wisconsin Power Company. Attendance 52.

May 23, 1922. Subject: "The Electrification of Northwestern Roads." Speaker: Mr. H. W. Williams, of the Chicago, Milwaukee and St. Paul Railway. Attendance 57.

University of Southern California.—May 24, 1922. Mr. Stewart, of Los Angeles, gave an interesting talk and demonstration of a new type variable-speed induction motor invented by him. Attendance 12.

Stanford University.—April 20, 1922. Subject: "Electric Ship Propulsion," (illustrated). Speaker: Mr. Rhine, of the General Electric Company. Attendance 24.

May 11, 1922. Subject: "The Manufacture of Incandescent Lamps" (illustrated). Speaker: Mr. Frellson, of the General Electric Company. Attendance 17.

Swarthmore College.—March 15, 1922. Subject: "Cottrell Process of Electrical Precipitation." Speaker: Mr. J. C. Fretz. Attendance 15.

Texas A. & M. College.—May 26, 1922. Election of officers as follows: Chairman, T. E. Keeton; vice-chairman, G. A. Hollowell; secretary-treasurer, R. S. Drake. Humorous talks were made by Dr. F. C. Bolton, and Professors Straw, Wooten, Sechrist and Yates. Attendance 76.

University of Virginia.—May 11, 1922. Election of officers as follows: Chairman, T. R. Bunting; secretary-treasurer, P. L. Weir. Subject: "The Electrification of the Transcontinental Line of the Chicago, Milwaukee and St. Paul Railway" (illustrated by slides and motion pictures). Speaker: Mr. J. A. Anderson, superintendent of the Milwaukee shops of the Chicago, Milwaukee and St. Paul Railway. Attendance 143.

State College of Washington.—May 26, 1922. Subject: "The Sperry Gyroscope." Speaker: President E. E. Johnson. Attendance 11.

June 6, 1922. Election of officers as follows: Chairman, C. R. Studer; vice-chairman, D. Merrin; secretary, E. J. Leahy; treasurer, Mr. O'Neal; reporter, Harold Vance. Attendance 11.

West Virginia University.—May 15, 1922. Subjects: "Three-Phase Current in Y-Connected Transformers" by C.B. Hutson; "The Electric Hammer" by I. O. Meyers; "The Electric Compass" by L. D. Tabler; "The Edison Effect" by W. D. Stump; "Electric Development During Last Decade" by J. R. Richards; "The Hydroelectric Situation" by A. E. LaPoe "Regenerative Braking" by R. Mendelsohn; "A Pilot-less Aeroplane" by R. Bowyers. Attendance 30.

University of Wisconsin.—May 24, 1922. Business meeting. Attendance 17.

Yale University.—May 17, 1922. Joint meeting of local branches of A. I. E. E., A. S. M. E., A. S. C. E. and A. I. M. E. Speakers: Mr. B. B. Gottsberger, professor-elect of Mining at Yale University, who spoke of the progress made in mining during the past years and the need of men in that branch of engineering; Dr. James R. Angell, president of Yale University, who spoke on "Professional Ideals." Attendance 125.

May 24, 1922. Subject: "Vitamines, in Every Day Life." Speaker: Dr. G. R. Cowgill, of the Department of Physiological Chemistry. Attendance 75.

May 25, 1922. Final meeting of school year. Open to stuents and members of faculty. A social time was enjoyed after a short talk by Professor Keller, of the department of social sciences, who spoke on some of the problems of society. Refreshments were served. Attendance 20.

Employment Service

The Employment Service announcements of which are published each month herein and which has been under the auspices of the Federated American Engineering Societies since the organization of that body about a year and a half ago, will pass back on July 1 to the direct jurisdiction of the societies concerned.

This Service, which was originally conducted separately by the Institute and some of the other national societies for the convenience of their members, was later carried on jointly under the management of the secretaries of the principal societies. When the Federation was formed this activity was transferred to that organization, which, however, arranged that the secretaries of the national societies of mechanical, mining, and electrical engineers should continue as a committee of management.

For several months past a committee of the Federation has studied the possibility of developing the Service into a more comprehensive organization; and in view of the fact that it is not possible for the Federation or its constituent societies to increase their present appropriation for this work, the possibility of establishing a paid service, with fees sufficient to make the bureau self sustaining, was also very carefully considered. One of the elements involved in the matter was the feeling on the part of the representatives of some of the local organizations that are members of the Federation, and that do not have publications of their own in which to give publicity to the activities of the Federation, that the Service as at present conducted cannot adequately meet the ambitions of their members. At a meeting of the committee in January a resolution was finally adopted outlining the various elements of the problem and recommending that the Employment Service be returned to the jurisdiction of the various constituent societies and that proper financial adjustments be made accordingly. The committee further called attention to the fact that the fundamental object of the F. A. E. S. is the rendering of service to the public, while the Employment Service is essentially personal, and therefore it is more feasible to carry it on by direct communication between the members concerned and the headquarters of their societies, inasmuch as the membership of the Federation consists of societies and not of individuals.

At a meeting of the Executive Board of the Federation held in Pittsburgh May 26-27, a resolution was accordingly adopted to the effect that the Employment Service be returned to the jurisdiction of the secretaries of the four Founder Societies, namely, the national societies of civil, mechanical, mining and electrical engineers, as of July 1, 1922.

The secretaries of these four societies have conferred regarding the matter and have already decided to recommend to their respective governing bodies that the present organization be taken over on July 1, and the service to the members of these societies be continued practically as heretofore. Plans for cooperation with other societies will also be considered later. It is generally agreed that so long as the service is continued without charge to either candidates for positions or prospective employers and the work supported entirely from funds appropriated from the treasuries of the societies concerned, it is not possible, and many of those directly concerned in the management of the matter believe that it is not desirable, that the societies should undertake to carry on employment activities to the extent of selecting and recommending one particular candidate for a particular position but should place the applicants fulfilling the requirements in touch with the employer, thus continuing to conduct an employment *information service*. The most valuable element of this service in the past has consisted in the opportunity afforded to members to have announcements published in the societies' journals relating both to available men and positions—in other words, for the bureau to act as a medium for the exchange of letters between applicants and prospective employers. Unless otherwise announced, therefore, it will be expected that the plan heretofore followed of publishing in the A. I. E. E. JOURNAL from month to month an Employment Service Bulletin, containing such announcements as referred to above, will continue, as for many years past, to be a feature of the monthly JOURNAL.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL **should be addressed to EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,** *the employment clearing house of the National Societies of Civil, Mechanical, Mining and Electrical Engineers.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case **and forwarded to EMPLOYMENT SERVICE,** *as above.*

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

OPPORTUNITIES

RADIO RESEARCH ENGINEERS & PHYSICISTS. University or commercial radio research experience. Must be able to plan and carry out independent experimental investigations in fields of short and long-distance wave transmission, radiotelephone receivers and transmitters, and kindred subjects. Write, including references to publications, experience, salary desired and time of availability. Salary not stated. Location, New York City. V-691.

CENTRIFUGAL PUMP DESIGNER. Manufacturer desires to correspond with experienced man on centrifugal pump design. Application by letter giving complete experience and qualifications with references. Location, Illinois. Salary not stated. V-1223.

SALES ENGINEER must have experience in the design, manufacture and assembling of controllers. Only experienced men will be considered. Application by letter giving age, education and experience. Salary not stated. Location, Pa. V-1225.

ENGINEER to have charge of the assembling of controllers. Must have design and shop experience in this line of work. Only experienced men will be considered. Application by letter giving age, education and experience. Salary not stated. Location, Pa. V-1226.

MANAGER of engineering department to have charge of testing and installation of radio receivers, also of service department. Must be good executive and experienced radio engineer. Application by letter giving full detail of experience, age, references and when services will be available. Salary not stated. Location, New York City. V-1239.

ELECTRICAL DRAFTSMAN, preferably with experience on transformers. Application in person. Location, Newark, N. J. V-1256.

ELECTRICAL OR MECHANICAL ENGINEER who has had experience in small switches and electrical apparatus. Specially trained man to do design work and eventually to come in charge of factory. Application by letter. Location, New York City. V-1270.

ESTIMATOR, young, experience in estimating construction of overhead distribution and transformer installations in suburban districts. Position with rapidly growing public utility in Western New York. Pay moderate to start until appli-

cant has demonstrated ability to earn more. Second choice young electrical student with good theoretical understanding of principles of overhead line construction and distribution. Exceptional opportunity for advancement. Application by letter giving all particulars. Location, New York State. V-1280.

ELECTRICAL ENGINEER (2), age 26-32, for local managers or superintendents in charge of local offices, handling commercial work, maintenance and operation of low-tension lines for power and light distribution. Protestant, American with operating and commercial experience preferably. Trained for 1-4 months. Application by letter. Location, Pittsburgh, Pa. V-1286.

DRAFTSMAN DESIGNER, electrical engineer, capable of laying out power house. Must have experience with large power company. Permanent position. Application by letter. Location, New York City. V-1288.

RADIO ENGINEERS (4) with designing and research experience. Application by letter. Location, New York City. V-1300.

ENGINEERING SALESMAN with experience in design and selling of centrifugal pumps. One with technical education preferred. Application by letter giving age, education and experience. Salary not stated. Location, Ontario, near Toronto. V-1328.

ENGINEER to do estimating and contracting for roofs. Must know all kinds of tar and felt roofs and be able to estimate and execute the work. Application by letter. Commission only. Location, New York City. V-1335.

SALESMEN to sell high grade window shades to architects, engineers and owners. Application in person. Commission. Headquarters, N. Y. City. V-1336.

ENGINEER to act as superintendent in small factory. Must have good personality and know something about steel, particularly cold rolled and drawn processes. Age 35 40. Willing to live in small city of about 50,000 population where living conditions are excellent, and will be but a few hours distant from large city. Application by letter. Location, Michigan. V-1350.

ENGINEER to handle sale of mechanical stokers. Must have some knowledge of same and boiler room practise. Give particulars of education, experience and aptitude for commercial work. Application by letter. Salary not stated. Headquarters, New York City. V-1352.

TECHNICAL GRADUATE who has had a few years experience. Work will consist of drafting and field work in connection with hydraulic power house extensions, substation and transmission line designs and construction. Application by letter stating age, whether married or single, experience, education, and amount of salary expected. Location, Pa. V-1382.

ASSISTANT TO DIRECTOR OF EDUCATION. Chief duty will be to handle certain electrical instruction and keep in close contact with instructional work. Qualifications—pleasing personality; good mixer; diplomatic; experienced in power plant work with some teaching experience; age not over 35 and preferably married. Position permanent for right man. Teaching year consists of eight months with remaining four months entirely free. Mornings will be free with some afternoon and considerable evening instruction. Application by letter. Location, New York. V-1388.

PHYSICIST OR ELECTRICAL ENGINEER (2) for development and engineering work on vacuum and gas-filled electrical devices. Post-graduate degree desirable. Application in person, by appointment. Location, New York City. V-1390.

RADIO ENGINEER for large electrical manufacturing company. Should be technical college graduate in electrical engineering, with experience in experimental radio development problems involving both transmitting and receiving. None but high-grade development engineers need apply. Application by letter stating age, education and experience. Salary not stated. Location, Pa. V-1402.

ELECTRICAL ENGINEER about 30 to act as supervisor of men laying out field work for overhead distribution lines. Should have experience in electric line construction. Work will consist of planning, drawing up specifications and ordering material. Application by letter. Location, Penna. V-1428.

STEAM POWER ENGINEER, by large industrial organization, to work up general engineering and sales data on steam power apparatus. Mechanical engineering graduate with about ten years experience in central station work and problems of combustion and heat balance required. Application by letter stating age, education and experience. Salary not stated. Location, Pa. V-1434.

OPERATING SUPERINTENDENT for electric light and power public utility company. Electrical engineering graduate preferred. Extensive experience in operation of steam plants and high-voltage transmission lines, substations, distribution system and meter work necessary. Ability to handle men successfully essential. Application by letter stating fully as to education, experience, qualifications and salary desired. Location, W. Va. V-1435.

SUPERINTENDENT of transmission and distribution system desired by public utility company to handle operation and maintenance of high-voltage lines and substations up to 60,000 volts. Also 2300 and 4000-volt distribution system. At least 8-10 years experience necessary. Engineering education desirable but not necessary. Application by letter giving full particulars and references. Location, W. Va. V-1436.

INSTRUCTOR for electric utility corporation. Technical man with teaching experience and knowledge of central station business to teach classes of new and old employees, in engineering and commercial branches. Application by letter. Send photograph and full particulars. Salary not stated. Location, Middle West. V-1439.

YOUNG ENGINEER with 4 or 5 years practical experience along the following lines for an old established concern, making a specialty of industrial power piping, heating, ventilating and fire protection. Permanent position with splendid opportunity for advancement. Application by letter stating fully experience and positions occupied. Salary not stated. Location, Mass. V-1440.

GENERAL ELECTRICAL DRAFTSMAN for electric shipwork. Application by letter. Location, New York City. V-1441.

ELECTRICAL ENGINEER with a few years experience on electric track work for heavy line operation. Application by letter stating age, education, experience. Salary not stated. Location, New York City. V-1442.

FACTORY SUPERINTENDENT to take charge of manufacture of portable electrical measuring instruments. Business small at present, but having been established for a number of years, is ripe for expansion. Must be thoroughly familiar with technical detail of design of ammeters, voltmeters and wattmeters, for use on both a-c. and d-c. Previous experience in manufacture of precision instruments although not absolutely required is highly desirable and all other factors being equal, preference will be given to such applicant. Superintendent will establish routine of manufacture and assembly, prepare standard specifications, giving limits, and in every way put business on organized engineering basis. In this connection, the engineer selected will be given carte blanche. Application by letter stating age, education and experience in detail. Salary reasonable and at stated time, if capabilities of engineer have been demonstrated, he will be given opportunity to secure substantial interest in corporation. Location, New York City. V-1446.

MECHANICAL ENGINEER with experience in design and construction of power presses, shears and other power sheet metal working machinery. Application by letter giving complete information. Salary depends on applicant. Location, Buffalo, N. Y. V-1459.

ENGINEER to teach subject of internal combustion engines. If possible would like man with some teaching experience, supplemented by considerable amount of practical experience. Work would consist of instruction in high-speed gasoline engine, tractor engine and heavy oil engines of the Diesel and semi-Diesel type. Rank will be that of full professor. Application by letter Would be able to increase yearly income to certain extent by outside consulting practise if so desired, so long as such practise did not interfere with college work. Term begins latter part of September. Location, Middle West. V-1464.

ASSOCIATE PROFESSOR of electrical engineering. Teaching experience and practical experience in electrical engineering work essential. Application by letter. Location South East U. S. V-1479.

ELECTRICAL ENGINEERING GRADUATE with between 3 and 5 years experience on valuation public utilities. In answering attach photograph and state date can report for duty. Application by letter. Salary not stated. Location, Middle West. V-1481.

ELECTRICIANS (2) capable of handling electrical instruction. Should be thoroughly familiar with practical work including conduit *B X*, knob and tube work, meter installations, switchboard and small power station operation and understand motor repairing and storage battery work. Application by letter. Salary not stated. Location New England. V-1482.

MACHINE TOOL SALESMAN with practical shop and tool room experience, thoroughly familiar with details of machinery business. Moderate investment desirable to establish sincerity, but not absolutely essential. Application by letter only giving details of past connections and experience. Salary and commission. Headquarters, New York City. V-1488.

BUSINESS MANAGER for manufacturing concern. One who has had broad business training covering thorough knowledge of sales, advertising, credits and knows high-grade machinery construction from shop standpoint. Prefer man who would interest himself financially and secure substantial interest in company. Salary dependent upon experience. Application by letter. Location, New York City. V-1489.

RECENT GRADUATES with degree in mechanical engineering for student engineering course offering valuable opportunity for experience in application of theory to practise. Men of pronounced mechanical and mathematical aptitude preferred. Application by letter or in person. Large manufacturing concern. Location, Mass. V-1501.

DESIGNING DRAFTSMAN with experience on mechanical end of electric elevators. Application by letter. Salary not stated. Location, N. Y. City. V-1511.

PRACTICAL MOTION PICTURE ENGINEER, one familiar with the art, practised in up-to-date methods of projection, familiar with automatic movements, conversant with patent art and if possible with technical education. Application by letter. Salary not stated. Location, New Jersey. V-1517.

SALES REPRESENTATIVES wanted for new concern manufacturing steam turbines. Preference given to men having one of following qualifications: 1. Graduate mechanical or electrical engineer. 2. Experienced in steam turbine design, manufacture of sales. 3. Established as a representative at present of some other concern selling pumps or power plant apparatus. 4. Established power plant contractor. Application by letter giving qualifications and references. Commission basis. Location, New York, Philadelphia, Pittsburg, Detroit, Cleveland, Chicago and Milwaukee territories. V-1518.

HYDROELECTRIC ENGINEER to design plant, select site, and construction. Application by letter. Location, New York State. V-1534.

DRAFTSMAN to handle ordinary plant work, including design of rail grinders and similar machines. Temporary, 3 months, may be permanent. Application by letter. Salary not stated. Location, New Jersey. V-1552.

ENGINEERS to work on design of controllers for elevators, cranes and hoisting machinery. Experience in design and application of control apparatus essential. Must have good knowledge of motor design and of hoist work both on direct and alternating current. Will pay reasonable salary depending upon ability of man. Permanent position. Application by letter. Location, California. V-1553.

MAINTENANCE ENGINEER with chemical plant experience, preferably dye plant. Must be able to design and equip additions to plant. Graduate engineer from well-known college. Should have had G. E.or Westinghouse test course. Application by letter. Location, N. J. V-1562.

TECHNICALLY TRAINED YOUNG MEN (2 or 3), interested in getting into selling end of illuminating and electrical engineering and contracting. Prefer men with experience in estimating and selling, but might consider training an exceptionally ambitious young man in our line. Compensation on commission basis with drawing account. Refined bearing, ability to present oneself, and adaptability, together with ardent desire to learn all details of work, are absolute essentials; positions permanent. Application in person, by appointment. Location, Brklyn., N. Y. V-1565.

YOUNG ELECTRICAL ENGINEER with electric signaling experience, estimating experience, etc. as estimators. Permanent position with future. Application in person. Location, New York City. V-1587.

ELECTRICAL ENGINEER for circuit analysis work, must know rate setting, method sheets, etc. Permanent with future. Application in person. Location, New York City. V-1589.

ELECTRICAL ENGINEER as technical investigator. Must be tactful, with good personality. Must know rate setting. Permanent. Application in person. Location, New York City. V-1590.

PARTNER to start contracting business in electrical equipment of buildings and mechanical equipment of factories. Requires both investment (about $5000) and ability to obtain and close contracts. Application by letter. Salary, division of profits. Location, New York City. V-1594.

BRANCH MANAGER, capable of conducting electrical supply and construction business of from 50 to 100,000 per year. Preferably one who has had experience in this line and has marked selling ability and executive ability. Application by letter. Salary not stated. Location, New York State. V-1597.

SALES ENGINEER experienced with electric clock and low-tension systems. Acquaintance with consulting engineers and architects in New York essential. Application by letter. Salary not stated. Location, New York City. V-1603.

ENGINEERS (8 or 9) with illuminating experience. Sales experience desirable. Will be located in district offices, and will be called district illuminating sales engineers. Application by letter. Headquarters, Indiana. V-1609.

ELEVATOR ENGINEER, an opening for man who can estimate on and execute general mechanical and electrical repairs, alterations and improvements to electric elevators Executive ability an advantage. Application by letter only giving qualifications, experience, salary, etc. Salary not stated. Location, New York City. V-1622.

ELECTRICAL ENGINEERING GRADUATE. This year's graduates to enter engineering department through drafting room. Apply by letter giving experience in detail, sample of lettering and photo. Salary not stated. Location, Western Pennsylvania. V-1634.

EXPERIENCED ELECTRICAL DESIGNING DRAFTSMAN familiar with making plans for large indoor and outdoor stations to take charge of drafting force sought by company in Toronto, Canada controlling several utilities in foreign countries. Application by letter only giving full experience record, salary expected and time when free to begin. V-1681.

METALLOGRAPHIST experienced in research work for investigations on electric filaments. Application by letter. Location, N. J. V-1679.

SALES ENGINEER. Young single man having practical experience with detail electrical switchboard apparatus, such as circuit breakers and instruments. Sales experience not necessary. State age, experience and salary expected. Location, Philadelphia territory. V-1683.

INSTRUCTOR in electrical engineering, duties commencing Sept. 15th. Must be a university graduate, preferably with one or two years practical experience in electrical work. Opportunity to pursue post-graduate studies. Application by letter giving qualifications and references. Location, New York State. V-1688.

MEN AVAILABLE

YOUNG MAN—Age 30, single, 3, years college course in E. E. With large street railway company for three years as expert trouble man central station work, and expert mechanic. For past four years supervisor in test and development work in radio for the U. S. Gov't. Fair knowledge of Spanish and French. Present salary $2500. Assoc. A. I. E. E. and I. R. E. E-3390.

ELECTRICAL ENGINEER—Age 27, single, Assoc. A. I. E. E. Will receive M. S. in E. E. from Cornell U. this June. Three years teaching experience. Three summers practical experience (two on Westinghouse Student Course and one with large N. Y. City operating company.) Would like to consider position with operating or manufacturing company of moderate size for several years practical experience before continuing teaching. Location, mid-west or west preferred. Salary, anything reasonable. Available after July 1st. E-3391.

RESEARCH ENGINEER, employed for a number of years by a large electrical manufacturing concern. Specialized in dielectric research, measurement of resistance, losses in insulating materials at commercial and radio frequencies, treatment of insulating materials for improving electrical properties, development of new methods of test, study of corona in air spaces in a dielectric. Wide experience in other lines of physical research. Reasons for desiring a change are, position of more responsibility and opportunity and advancement in salary. E-3392.

SALES MANAGER, graduate electrical and mechanical engineer, University California, fourteen years experience, desires connection sales executive property or company requiring commercial expansion and rejuvenation and where permanent future and advancement will depend upon new revenues produced. At present employed. Communications with high types of organizations solicited. E-3393.

ELECTRICAL ENGINEER or ELECTRICAL SUPERINTENDENT. Practical, energetic man, 44 years of age, married, with 15 years experience with all classes of electrical apparatus, transmission lines, substations and large pumping plants. Location desired; West Coast or Latin America. Excellent references. Available immediately. E-3394.

GENERAL MANAGER—Over twenty years experience in construction, operation, management public utilities. General manager large railway, gas and power company prior to the war. Know the business from the coal pile to the public. Successful executive, energetic and tactful. Age 47, married, American, several years experience abroad, speak Spanish. Available now. E-3395.

PROFESSORSHIP IN ELECTRICAL ENGINEERING, HEAD OF DEPARTMENT, DEAN OF ENGINEERING, OR PRESIDENT OF TECHNICAL SCHOOL desired by engineer qualified by years of successful teaching and administration and by responsible experience in the construction, operation, valuation and regulation of utilities. Exceptional references. E-3396.

TECHNICAL GRADUATE in ELECTRICAL ENGINEERING, 3 years G. E. Test and transformer engineering dept. One year power house and substation construction. Five years as engineer on the design, construction and development of electric furnaces in brass industry, either domestic or foreign service. Available June 15. Assoc. A. I. E. E. E-3397.

ELECTRICAL SCHOOL GRADUATE wishes a job where he can get good practical experience, and where there is chance to advance. Has had two years experience with steam engines and boilers. E-3398.

RADIO and GENERAL ELECTRICAL experience of young man of 30 available on or after June 1st. Desire connection preferably with some large organization, shop or store intending to develop its radio and electrical trade. E-3399.

ELECTRICAL ENGINEER, B. S. in E. E., A. B., single, 23, experienced in electrical contracting and public utility construction, desires position with power plant construction company. References furnished. Location immaterial. E-3400.

YOUNG MAN (M. I. T. 1922) wishes position in the electrical line somewhere in the East (New England preferred). Six months W. E. & M. Co. test. Some machine-shop experience. Available after June 15th. E-3401.

INSTRUCTOR IN ELECTRICAL ENGINEERING desires position as instructor or assistant professor in electrical engineering at technical school or university. Three years experience in teaching electrical engineering and over a year's practical experience with large manufacturing company. Graduate of 1917. E-3402.

GRADUATE ENGINEER, B. Sc., in Electrical engineering, U. of Pa. 1921. Student member A. I. E. E. Age 22. Single. Has had little practical experience. Desires position with public utility or manufacturing company. Opportunity for advancement more important than good salary. E-3403.

YOUNG ELECTRICAL ENGINEERING GRADUATE, age 22, desires position as instructor or as junior engineer where there is sure chance of advancement. Graduate of good technical school and of school of drafting. One year experience as electrical contractor, 1 year 6 mo. experience in telephone and power testing, one year experience as instructor. Location East. Present salary $1800. E-3404.

GRADUATE ELECTRICAL ENGINEER. Age 27, married, desires position with light and power or traction company. One year junior engineer with power and traction company, all departments, two years general business experience. E-3405.

ENGINEER desires to secure representation in Mexico, Cuba or South America. Graduate mechanical engineer with four years selling experience in electrical industry. Thorough knowledge of Spanish and customs in Latin America. Age 32. Compensation salary or commission or both. Assoc. A. I. E. E. E-3406.

TECHNICAL GRADUATE, B. S. in E. E., June. Age 27, single. Two years experience in steam and hydroelectric plant. Northern Michigan previous to college. Desires position with hydroelectric company preferably in Western States. Opportunity, not immediate salary, primary consideration. E-3407.

GRADUATE GAS AND ELECTRICAL ENGINEER, Age 33, married. Technical degrees, B. S., M. S. & E. E. Assoc. A. I. E. E. Member A. G. A. Nine years practical gas and electric public utility operation in responsible capacity. State Public Service Commission Engineer. Prefer public utility work. Now in New York. Location anywhere. E-3408.

ASSOCIATE OR ASSISTANT PROFESSORSHIP ELECTRICAL ENGINEERING desired. University teaching experience. Now technical sales engineer in modern central station. Gradu-

ate 1910. Age 36. Married. American, of English descent. Eight years experience teaching, four as associate or head of dept. Four years diversified practical experience in both central station and telephone engineering. Qualified for teaching technical theory and commercial practise in university. Also, experienced in University extension courses. E-3409.

ELECTRICAL ENGINEER, technical graduate; Assoc. A. I. E. E. Age 28. Six years experience in testing laboratory radio, chief engineer of marine installation and maintenance; remote control, machine tool application, estimating and construction work. Desires permanent position with well established company, planning, estimating and following up progress of jobs. Location preferred Newark or New York City. Available one month. E-3410.

ELECTRICAL ENGINEER, Technical graduate, married, age 26, desires position where combination of analytical, sales, and technical ability is required. Instructor in government electrical school for enlisted specialists, 1½ years successful sales experience with electrical jobbing house, 1 year design Westinghouse E. & M. Co., including company's technical training. Have initiative and perseverance. Now employed. Available on short notice. Location anywhere. E-3411.

YOUNG ENGINEER desires position with engineering firm or technical school with duties of hydroelectrical nature. Successively school superintendent, naval officer (radio), university instructor, Fellow studying hydroelectrical engineering in Europe. Ph. B., M. S. Age 27. Married. Available, middle August. E-3412.

GRADUATE, Harvard College, and mechanical and electrical engineering courses at Massachusetts Institute of Technology, desires position in electrical research or design, preferably near Providence, Rhode Island. Draughting not considered. Now with large public utility. E-3413.

DEVELOPMENT ENGINEER, University graduate with three years experience in development of manufacturing processes with large electrical manufacturing company. Desires development of electrical apparatus of any kind, or any line of work requiring practical application of the fundamental engineering laws. Age 27. Prefer middle western location. E-3414.

ELECTRICIAN—first class, age 37, 20 years experience in repair maintenance and construction, desires position as chief or assistant in manufacturing plant. E-3415.

MECHANICAL and POWER ENGINEER, technical graduate, B. S. and M. E., eight years experience along broad lines, machine shop, metallurgy, sugar engineering, industrial and power plant practise and operation, design, layout, calculations, heat-balance, utilization and distribution of steam, water, coal, power, etc., investigation, research reports. E-3416.

ELECTRICAL ENGINEER — Assoc. A. I. E. E., age 30, married. Installation—a-c. and d-c., laboratory, experimental and general test. Completing 2-year engagement power and lighting installation in large modern factory. Can handle men. Experience 9 years Canadian, 2 years European, 3½ years war service. Now located in England. Present salary $3500. E-3417.

ELECTRICAL ENGINEER with over 20 years experience in the layout, erection and maintenance of electric equipments and plants, seeks position as superintendent of construction with contracting company or as electrical superintendent in charge of factory or mill plant, or with consulting engineer. E-3418.

ELECTRICAL CONSTRUCTION SUPERINTENDENT—American, Age 37, over ten years experience supervising installation of central and substation equipment and building bus and switch compartments for potentials up to 11,000 volts. Capable of organizing and handling men. Willing to assume responsibility, and work hard. Location anywhere. Salary $3600. E-3419.

GRADUATE ELECTRICAL ENGINEER—age 25—has had experience in electrical station construction and operation desires position with engineering departments of some public utility company where there is a chance to obtain advancement. E-3420.

YOUNG ENGINEER. Age 26. Technical education. Seven years in the electrical field, including laboratory construction and installation work. Completed electrical engineering evening course at Columbia University, New York City. Desires permanent position in Cuba. E-3421.

ELECTRICAL ENGINEER with over sixteen years shop, office and field experience with largest construction and manufacturing companies in U. S. A. and abroad. Thoroughly competent to supervise the electrical construction and design of central and substations and factories either high or low tension. University graduate, age 43, at present employed by one of the largest public utility companies in the East. Would consider position commensurate with ability. E-3422.

TELEPHONE ENGINEER, technical graduate, age 28, single, desires permanent position with telephone operating or manufacturing company, state utilities commission or consulting engineer. Six years experience in telephone work in private and governmental employ under general supervision. Familiar with outside plant design and construction, well versed in circuit operation, manual and automatic. Some knowledge of commercial and traffic studies; capable of considering telephone problems along broad lines. E-3423.

ELECTRICAL ENGINEER, 34, experienced in transmission line, substation, distribution, steam and hydroelectric station, interurban railway, gas manufacturing, inductive interference, electrolysis mitigation, automobile fleet operation, stock handline, with initiative and executive ability, desires position as superintendent or engineer. Employed. Preferably Ohio or nearby state. E-3424.

EXPORT ENGINEER or foreign representative. Young electrical engineer, single, technical graduate with practical experience; in Europe 1920 and 1921 for American institution, desires position here or abroad in export department of electrical manufacturer. Fluent French, some German, Italian, and Spanish. Expects preliminary training period. E-3425.

ENGINEER, 22 years of age with electrical engineering degree from M. I. T. desires position along either commercial or technical lines. Has specialized in illumination. New York City and vicinity, or Boston preferred. E-3426.

SALES ENGINEER, M. I. T. 1918. Single. Now with company producing road and dam construction equipment. Desires position with company associated with electrical industry. Has had production and testing experience with motor manufacturers. Available on reasonable notice. E-3427.

ELECTRICAL ENGINEER—Technical graduate, age 24, single; six months as electrical contractor, 3 months on automatic telephones, 2 months as traveling salesman. Desires position with engineering or manufacturing concern which offers chance for advancement. E-3428.

RECENT TECHNICAL GRADUATE—B. S. degree in electrical engineering. Age 24. Single. Desires position with engineering or manufacturing company. Opportunity, not immediate salary primary consideration. Little practical experience. Any location. E-3429.

ENGINEER, age 30, married, Cornell graduate, A. I. E. E., Protestant. Westinghouse engineer five years; electric power and railway over three years. Equipped to serve as assistant to executive officer or assume responsible charge. Familiar with rate and commission cases, statistical work, analysis of operations and economic problems, special investigations and engineering reports. E-3430.

ELECTRICIAN, age 30, 12 years experience in operation and maintenance of electrical machinery, also engineering and test work. Assoc. member A. I. E. E. also a student of electrical engineering, I. C. School. At present employed but desires change, where there is a chance for advancement. E-3431.

GRADUATE ELECTRICAL ENGINEER, Assoc. A. I. E. E., six years experience design and estimating on power plants, substations, distribution and transmission systems, desires responsible, permanent position leading toward executive position. Now employed but available on short notice. E-3432.

ASSISTANT CHIEF ENGINEER and SUPERINTENDENT. Graduate elec. eng., age 36, 17 years experience supervising designs, construction and operation of power and substations, industrial plants, transmission systems, and handling reports on investigations for electrolysis, desires position where high class executive ability is required. E-3433.

ELECTRICAL AND MECHANICAL ENGINEER—experienced in electrical and mechanical operation and maintenance of industrial plants. Thoroughly familiar with electrical construction and contracting work and steam plants. Now available. E-3434.

CONSTRUCTION MAN. Two years of technical education, six years of practical experience in construction and installation of central and substations indoor and outdoor types. Also industrial installation. Executive ability, not afraid of work, location immaterial. Available on ten days notice. E-3435.

SALES ENGINEER, age 36, wants position. Successful as salesman and district sales manager. Foundation as electrical engineering graduate four years construction and operation and testing course large manufacturer. Nine years industrial sales engineering. Perhaps a public utility or manufacturer could use his services best. Highest references as to business qualifications and personality. E-3436.

OPPORTUNITY sought by graduate electrical engineer. American, age 37. Past student Alexander Hamilton Institute business course and personal subscribers to Babson's Reports. Experience includes Westinghouse apprenticeship, electrical construction inspection and thirteen years engineering-sales, department managership and manufacturers' agent. Future possibilities more important than immediate remuneration. Available now. E-3437.

TECHNICAL GRADUATE—22, no electrical experience, but willing. Speedy typist-stenographer. Power (gas, gasoline, oil engine) sales correspondent. Desires chance as assistant to consulting engineer—preferably on hydroelectric developments. E-3438.

RECENT GRADUATE in electrical engineering with B. S. degree. Age 23, married, enrolled student A. I. E. E. One year's experience in substation. Desires position with industrial concern offering opportunity for advancement. Location immaterial. E-3439.

OPERATING ELECTRICAL ENGINEER. Age 29, married, desires to locate in British Columbia. 13 years experience in operation and maintenance of hydro plants and substations, electrolysis survey, block signaling and various other phases in the operation and maintenance of an electrical utility. Holding *executive position* at present. E-3440.

ELECTRICAL ENGINEER. Associate A. I. E. E., technical graduate, age 32, with 12 years' practical experience in engineering and construction, covering the responsibility of designing, laying out work, supervising, estimating, executive engineer and vice-president, desires position affording opportunity. E-3441.

CHIEF ELECTRICIAN, with 15 years practical experience mostly on d-c. in steel mills and other industrial plants. At present have charge of electrical dept. in steel mill where I have been employed for more than 5 years. Would like to make a change to a higher latitude. E-3442.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED JUNE 29, 1922

ADAMS, HAROLD, Electrical Tester, General Electric Company, Lynn; res., 513 Summer St., West Lynn, Mass.

AHRENS, WILLIAM EDWARD, Division Plant Engineer, The Pacific Tel. & Tel. Company; res., 5012, 11th Ave., N. E., Seattle, Wash.

ALBERT, NORMAN MURRAY, Student, Electrical Engineering Course, General Electric Co.; res., Thomson Club, Baker St., Lynn, Mass.

AMAN, WALTER F., Laboratory Assistant, Bureau of Standards, 312 East Bldg., Washington, D. C.; res., Mt. Rainier, Md.

ANDERSON, FRANS I., Secretary-Manager, Sultan Electric Company; Granite Falls Electric Company, Sultan, Wash.

ANDRIX, EARL R., Superintendent of Power, Columbus Railway, Power & Light Company; res., 828 Bellows Ave., Columbus, Ohio.

ARLAND, FREDERICK LEON, Assistant Engineer, New York Telephone Company, 104 Broad St., New York, N. Y.

ASKE, IRVING ELSWORTH, President & General Manager, Kase Electric Company, 14 Sherwood Bldg., Duluth, Minn.

ASSET, HENRY LOUIS, Engineer, Framerican Industrial Development Corp., 21 E. 40th St., New York; res., 615 E. 32nd St., Brooklyn, N. Y.

ATHERTON, HAROLD, Electrician, Canadian Tungsten Lamp Company, Ltd., Hamilton, Ont.

AUSTIN, HARVEY B., Manager, Electrical Development & Machine Company, 221-227 N. 23rd St., Philadelphia, Pa.

BABCOCK, ROBERT, 1st Class Electrician, Brooklyn Edison Company, 360 Pearl St.; res., 75A Willow St., Brooklyn, N. Y.

BACON, CHARLES A., Electrical Engineer, Adirondack Power & Light Corp., Amsterdam; res., Fonda, N. Y.

BAKER, FREDERICK KERSLAKE, Operator, Transformer Station, Hydro-Electric Power Commission, Falls View; res., 8 Forest Apts., Symms Ave., Niagara Falls, Ont., Canada.

BAKER, J. A., Foreman, Electrical Repairs, Dodge Bros., Detroit, Mich.

BALCH, ELWYN C., Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

BARNER, JOHN H., Chief Electrician, Minnesota Electric Light & Power Company, 109 W. Broadway, Cushing, Okla.

BATTLE, ROBERT T., Proprietor, Robert T. Battle Company, 220 W. 42nd St., New York, N. Y.

BAUER, JOHN H., Member of Firm, Bauer & Company, 449 Asylum St.; res., 66 Canterbury St., Hartford, Conn.

BECK, THEO W., Foreman, Ogden Electric Supply Company; res., 953 23rd St., Ogden, Utah.

BENTLEY, FRANK H., Salesman, Aluminum Company of America, 705 Mutual Home Bldg., Dayton, Ohio.

*BERSEY, WALTER S., 805 Seymour St., Lansing, Mich.

BETTIS, ALEXANDER E., Superintendent, Kansas City Power & Light Company, 1330 Grand, Kansas City, Mo.

*BISHOP, TRENHOLME ALLEN GILL, Engineering Dept., Montreal Public Service Corp.; res., 9 Summerhill Ave., Montreal, Que.

BLAMEY, CHESTER A., Foreman, Citizens Electric Company, Hot Springs, Ark.

BLANCHARD, NATHANIEL W., Junior Electrical Engineer, Transit Commission, 49 Lafayette St., New York; res., Woodmere, N. Y.

BORLAND, JAMES EASTHAM, Electrical Engineer, Westinghouse Elec. & Mfg. Company; res., 711 Hazelwood Ave., Pittsburgh, Pa.

BRADSHAW, THOMAS NORWOOD, Outside Plant Engineer, The Southern New England Telephone Company, New Haven; res., 225 William St., West Haven, Conn.

BRAATEN, INGVALD T., Fellow, American-Scandinavian Foundation, Lille Strangt, Christiania, Norway; 36 Franklin St., Auburn, N. Y.

BRIAN, ALFRED, District Manager, Canadian General Electric Company, Ltd., Cobalt, Ont.

BRIGGS, JOHN BOURCHIER, Chief Operator, High Falls Power House, Superintendent, Rideau System, Hydro-Electric Power Commission, Dalhousie Lake, Ont.

BROADBENT, HAROLD STANLEY, Commercial Engineering Dept., Westinghouse Lamp Company, Bloomfield, N. J.

BROWN, CHARLES D., Electric Testing Division, The Milwaukee Electric Railway & Light Company; res., 714 52nd St., Milwaukee, Wis.

BUCHANAN, GEORGE ALBERT, Designing Engineer, Salt River Valley Water Users' Association, Phoenix, Ariz.

BURKHART, PAUL HENRY, Instructor in Electrical Engineering, University of Illinois, Urbana, Ill.

BURNES, GEORGE W., Manager, Schiefer Electric Company, Ellicott Square, Buffalo, N. Y.

BURNS, HARRY ROBERT, Engineer, Union Gas & Electric Company, Cincinnati, Ohio.

BURRELL, EUGENE J., Manager, Production Dept., Victor X-Ray Corp., 236 S. Robey St., Chicago, Ill.

BUSHNELL, SAMUEL K., Sales Manager, Dayton Office, Aluminum Company of America, 705 Mutual Home Bldg., Dayton, Ohio.

*BUSS, RUSSELL S., Telephone Equipment Engineer, Western Electric Company, 463 West St., New York, N. Y.

CALDWELL, GEORGE WOODWORTH, Plant Dept., American Tel. & Tel. Company, 24 Walker St., New York; res., 256 Garfield Place, Brooklyn, N. Y.

CAMERON, DONALD LOCHIEL, Testing Dept., General Electric Company; res., 128 University Place, Schenectady, N. Y.

CAMPRUZANO, GEORGE L., Draftsman, William Cramp & Sons Ship & Engineering Building Company; res., 5036 Spruce St., Philadelphia, Pa.

CANFIELD, DONALD T., Assistant Instructor, Electrical Engineering Dept., Purdue University; res., 829 N. Salisbury St., W. Lafayette, Ind.

CASSEL, DANIEL EUGENE, Foreman, Winding Dept., Westinghouse Elec. & Mfg. Company; res., 666 N. Frazier St., Philadelphia, Pa.

CAYOT, RAMON A., Operator, Pacific Gas & Electric Company, Alta, Calif.

CHARLTON, JOHN R., Long Lines Engineering Dept., American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

CLARKE, OLIVER H.P., Electrical Engineering, Western Electric Company, 463 West St., New York, N. Y.; res., 4352 Maryland Ave., St. Louis, Mo.

CODE, FRANCIS LESLIE, Electrical Engineer, Hydro-Electric Power Commission of Ontario; res., Engineers Club, 32 St. Clair Ave., Niagara Falls, Ont.

COLUMBUS, ADOLPHE EUGENE, Foreman, Electric Construction, G. F. Bonham; res., 1329 H St., N. E., Washington, D. C.

*CONNELL, LAWRENCE H., Engineer, Samson Electric Company, 44 The Fenway, Boston, Mass.

COOK, NICHOLAS, "Insideman", Central Office, New York Telephone Company, 170 Paterson St., Paterson; res., Little Falls, N. J.

CUMMINGS, GEORGE WITTE, Engineering Dept., Edison Lamp Works, General Electric Co., Harrison, N. J.; 557 N. 11th St., Muskogee, Okla.

CURRIN, H. P., Electrical Engineer, Eastern Oregon Light & Power Company, Baker, Oregon.

*DANCEY, WILFRID ALAN, Demonstrator, Dept. of Electrical Engineering, University of Toronto; res., 23 Surry Place, Toronto, Ont., Canada.

DARST, VALENTINE WINTERS, Electrical Salesman, Commonwealth Edison Company, 1427 Edison Bldg., Chicago, Ill.

*de MEY, CHARLES FREDERIC, Engineer, Electrical Engineer's Office, The Hudson Coal Company, Scranton, Pa.

DETTRA, PAUL RICHARD, Inspector, Engineering Dept., Potomac Electric Power Company; res., 4000 5th St., N. W., Washington, D. C.

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Total 268.

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FELLOW REELECTED JUNE 29, 1922

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LEWIS, CHARLES GRANDISON, Sales Agent, Westinghouse Electric & Mfg. Company, 301 Liberty Bldg., New Haven, Conn.

LIEBENBERG, ARTHUR JOHN, Chief Electrical Engineer, The Warner Elevator Mfg. Company, 2613 Spring Grove Ave., Cincinnati, Ohio.

LLOYD, HERBERT M., Mechanical Assistant British Columbia Electric Railway Company, Vancouver, B. C.

LYNGE, CARL MELBY, Manufacturing Engineer, General Electric Co., Bridgeport, Conn.

MARSHALL, HARRY B., Manager, Railway Dept., Electric Storage Battery Company, 19th & Allegheny Ave., Philadelphia, Pa.

MORRIS, SHIRAS, President, The Hart & Hegeman Co.; The Johns-Pratt Co.; Hartford, Conn.

O'CONNOR, JOHN FRANCIS, Electrical Engineer, The Toledo Edison Company, Toledo, Ohio.

PESCOD, HENRY THOMAS, Electrician, All American Cables, Inc., Balboa, C. Z.

PRENNER, I. S., Technical Patent Expert, Penfield Bldg., Philadelphia, Pa.

ROBERTS, IRVING T., Chief Electrical Engineer, Sanitary District of Chicago, 910 S. Michigan Ave., Chicago; res., 1140 Maple Ave., Evanston, Ill.

SCHMIDT, WALTER A., President & General Manager, Western Precipitation Company, 1016 W. 9th St., Los Angeles, Calif.

SCOTT, WILLIAM M., Superintendent, Electric Service Dept., Utah Power & Light Company, Salt Lake City, Utah.

SMEATON, CHARLES A., Engineer, William A. Baehr Organization, 2013 Peoples Gas Bldg., Chicago, Ill.

TRIMINGHAM, JAMES HARVEY, Chief Engineer, Southern Canada Power Company, Ltd., Christine Bldg., Montreal, Que.

WAGNER, MILTON HENRY, Manager, Electrical Dept., The Charles M. Kelso Company, 1063 Reibold Bldg., Dayton, Ohio.

WILLIAMSON, ADRIAN ALFRED, Dept. of Operation & Engineering, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

FELLOW ELECTED JUNE 29, 1922

CULVER, CHARLES AARON, Chief High-Frequency Engineer, Canadian Independent Telephone Company Co., Ltd.; res., 202 Jarvis St., Toronto, Ont.

MORSE, GEORGE HART, Sales Engineer, H. M. Byllesby & Company, Inc., 111 Broadway, New York, N. Y.

TRANSFERRED TO GRADE OF FELLOW JUNE 29, 1922

ALLEN, EDWIN W., Asst. District Manager & District Engineer, General Electric Co., Chicago, Ill.

ALLEN, ELBERT G., Chief Engineer, Philadelphia Rapid Transit Co., Philadelphia, Pa.

HARRIES, GEORGE H., Vice-President, Byllesby Engineering & Management Corp., Chicago, Ill.

JAMIESON, BERTRAND G., Engineer of Inside Plant, Commonwealth Edison Co., Chicago, Ill.

PENNELL, WALTER O., Chief Engineer, Southwestern Bell Telephone Co., St. Louis, Mo.

ROBINSON, CHARLES A., Chief Engineer, Chesapeake & Potomac Telephone Co., Washington, D. C.

SMITH, ARTHUR BESSEY, Chief Research Engineer, Automatic Electric Co., Chicago, Ill.

SWOPE, GERARD, President, International General Electric Co., New York, N. Y.

TAYLOR, EDWARD, Electrical Engineer, General Electric Co., Chicago, Ill.

TRANSFERRED TO GRADE OF MEMBER JUNE 29, 1922

ABBOTT, WILLIAM R., President, Illinois Bell Telephone Co., Chicago, Ill.

ALGER, PHILIP L., Electrical Engineer (Designing), General Electric Co., Schenectady, N. Y.

ARMBRUST, GEORGE M., Engineer, Electrical Engineer's Office, Commonwealth Edison Co., Chicago, Ill.

BOSE, SURENDRA NATH, Engineer, Electrical Dept., Perin & Marshall, New York, N. Y.

BROPHY, JOHN J., Electrical Engineer, Turner Tanning Machinery Co., Peabody, Mass.

CALDWELL, O. H., Editor, *Electrical Merchandising*, New York, N. Y.

COUP, FRED T., District Manager, Wagner Electric Mfg. Co., Concinnati, O.

DEBEECH, ALBERT V., Electrical Research Engineer, Interborough Rapid Transit Co., New York, N. Y.

DES CAMP, EDWIN J., Sales Engineer, Western Electric Co., Inc., Seattle, Wash.

DORTING, E. E., Lighting Engineer, Interborough Rapid Transit Co., New York, N. Y.

FERRARI, CHARLES, Technical Manager, Societe Meridionale di Electricita, Naples, Italy.

FOWLER, MYRON M., Electrical Engineer, General Electric Co., Chicago, Ill.

FOX, WILLIAM A., Vice-President, Commonwealth Edison Co., Chicago, Ill.

GIERSCH, RICHARD F., JR., Construction Engineer, Cleveland Mill & Power Co., Lawndale, N. C.

GILBERT, HENRY C., JR., Construction Superintendent, W. A. Jackson Co., Chicago, Ill.
HIGMAN, H. LAWTON, Divisional Maintenance Supt., Ebro Power Co., Barcelona, Spain.
HOBBINS, WILLIAM D., Chief Engineer, Wisconsin Telephone Co., Milwaukee, Wis.
JOYCE, HARRY B., Chief Engineer, Centrifugal Fan Co., Newark, N. J.
KOBAK, EDGAR, Manager, *Electrical World, Electrical Review*, and *Industrial Engineer*, New York, N. Y.
KOUWENHOVEN, WILLIAM B., Associate Professor of Electrical Engineering, Johns Hopkins University, Baltimore, Md.
LA MOTTE, WILLIAM R., Chief Engineer, Perth Amboy Power Station, Public Service Electric Co., Perth Amboy, N. J.
LANPHIER, BASIL, Electrical Research Engineer, Interborough Rapid Transit Co., New York, N. Y.
LITTLER, RAYMOND G., Owner and Manager, West Coast Engineering Co., Portland, Ore.
OSGOOD, HARRY W., Electrical Engineer, McClellan & Junkersfeld Inc., New York, N. Y.
PERRY, CHARLES T., Electrical Engineer, City Department of Plant and Structures, New York, N. Y.
PLACE, CLAUDE W., Engineer, General Electric Co., Chicago, Ill.
POUPART, ERNEST, Electrical Engineer, Lake Shore Mines, Ltd., Kirkland Lake, Ont.
PRESCOTT, RICHARD D., Inspector General Tel. & Tel. Panama Government, Panama, R. P.
ROBINSON, CHARLES G., Superintendent, Electric Power Plants, Union Electric Light & Power Co., St. Louis, Mo.
ROCKWELL, ROBERT L., Consulting Engineer, Seattle, Wash.
STEVENS, ROGER B., Electrical Engineer, Consulting Board, American Sugar Refining Co., New York, N. Y.
TRUESDELL, JAMES W., General Manager, Electric Contractors Corp., Waterbury, Conn.
TUCKER, JESSE O., Supt. of Overhead, St. Louis Electrical Terminal Ry. Co., St. Louis, Mo.
WELGE, D., Chief Electrical Engineer, Bluestone Mining & Smelting Co., Mason, Nev.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings held April 10 and June 23, 1922, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

ARNOLD, J. LORING, Professor of Electrical Engineering, New York University, New York, N. Y.
FIELD, CROSBY, Engineering Manager, National Aniline & Chemical Co., Inc., New York, N. Y.

To Grade of Member

BEHRENS, EDWARD L., Muskegon, Mich.
BILLS, FRANK B., District Superintendent, Kinloch Long Distance Telephone Co., St. Louis, Mo.
BISCHOFF, LOUIS G., Transmission & Protection Engineer, Indiana Bell Telephone Co., Indianapolis, Ind.
CALDERWOOD, HUGH A., Professor of Electrical Equipment—Department Head, Carnegie Institute of Technology, Pittsburgh, Pa.
CURTIS, GEORGE S., Assistant Division Supt., Public Service Electric Co., Paterson, N. J.
EMERSON, CHARLES W., JR., General Foreman, Meter & Test Dept., United Electric Light & Power Co., New York, N. Y.
FURNAS, W. C., Assistant Superintendent, Electrical Dept., Allis-Chalmers Mfg. Co., West Allis, Wis.
FUSSELL, LEWIS, In charge of Engineering Department, Swarthmore College, Swarthmore, Pa.
HORLE, LAWRENCE C. F., Consulting Electrical Engineer, New York, N. Y.
KELLY, JOSEPH T., JR., Directing Engineer, Foreign Trade Department, Ohio Brass Company, Paris, France.
RAMEY, BLAINE B., Section Engineer, Westinghouse Electric & Mfg. Co., East Springfield Plant, Springfield, Mass.
ROFFEY, MILES H., Professor in Charge of Electrical Department, Honkong University, Hongkong, China.
UHL, ARTHUR W., Experimental Electrical Engineer, Ford Instrument Co., Inc., New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before July 31, 1922.

Adams, Norman, I., Jr., Lexington, Mass.
Ahrens, Ortgies, Jr., New York, N. Y.
Anderson, Frank H., New York, N. Y.
Ansingh, Herman K., (Member) E. Pittsburgh, Pa.
Ash, Philip P., Henderson, Ky.
Bassett, Walter G., New York, N. Y.
Bemis, Paul D., New York, N. Y.
Bickelhaupt, Carroll O., (Member), New York, N. Y.
Bloem, Cornelius J. C. M., (Member), Plainfield, N. J.
Bloom, Frank A., Alpena, Mich.
Brain, Vivian James F., Schenectady, N. Y.
Burd, Harry G., New York, N. Y.
Burkhead, Calvin H., Seattle, Wash.
Castagnaro, Dominick, Brooklyn, N. Y.
Chace, Myron D., Boston, Mass.
Colebert, Reed J., Wellsville, N. Y.
Connotte, Thomas W., (Member), Lockport, N. Y.
Cronin, Vincent P., Cambridge, Mass.
Davison, Alexader, Trail, B. C.
Digby, John C., New Westminster, B. C.
Dougherty, Samuel McC., Chicago, Ill.
Dunmire, Alvin L., Oakland, Cal.
Eddy, Wilton, N., Schenectady, N. Y.
Fargher, William G., Montesano, Wash.
Fenninger, William N., (Member.) Brooklyn, N. Y.
Forbath, John, New York, N. Y.
Fowler, Thomas C., Cleveland, Ohio
Fulcher, W. H., (Member), Cape Charles, Va.
Furui, Shungo, Stanford University, Cal.
Gale, Lionel G., Boston, Mass.
Giangrasso, Joseph V., New York, N Y.
Goddard, Charles W., Preston, Ont.
Green, Kenneth F., (Member), Prairie du Sac, Wis.
Greer, Robert T., Baltimore, Md.
Gunn, Ross, Oberlin, Ohio
Hager, Wayne, Galesburg, Ill.
Hansen, Aug., E., St. Paul, Minn.
Heath, Charles E., Los Angeles, Cal.
Hopkins, Lawrence L., Schenectady, N. Y.
Jacob, William F., Schenectady, N. Y.
James, Harold B., Cincinnati, Ohio
Karpov, Alexander V., (Member), Pittsburgh, Pa.
King, William C., Los Angeles, Cal.
Kinkaid, Charles P., Seattle, Wash.
Krigel, Joseph A., Great Lakes, Ill.
Laskey, Harry S., Toledo, Ohio
Le Blanc, Aime, (Member), Schenectady, N. Y.
Lindblad, William N., San Francisco, Cal.
Major, Oscar S., Kansas City, Mo.
Mather, Robert H., Windsor Locks, Conn.
McEntee, Frank J., Megath, Wyoming
Meek, Cecil P., Chicago, Ill.
Mendenhall, Ivan S., Detroit, Mich.
Meyerend, Frank M., New York, N. Y.
Miglioro, Erminio, Providence, R. I.
Morch, Philip C., Brooklyn, N. Y.
Moskowitz, Israel, New York, N. Y.
Mowry, Allen H., New York, N. Y.
Murdock, Edward S., St. Louis, Mo.
Naylor, Joseph E., Chicago, Ill.
Nelson, Harold F., New York, N. Y.
Nixon, Richard O., Philadelphia, Pa.
O'Connor, Joseph H., Fairfield, Ohio
O'Neill, Charles, Las Vegas, Nev.
Pawling, Richard L., Roosevelt, Ariz.
Pine, Robert B., New York, N. Y.
Quermann, George H., St. Louis, Mo.
Ralph, Arthur J., New Haven, Conn.
Rau, David S., Port Jefferson, L. I., N. Y.
Rosenkranz, Charles, Brooklyn, N. Y.
Scannell, Horatio C., Toledo, Ohio
Schimpff, Oscar Joseph, New York, N. Y.
Schindler, Edward H., Stanford, Conn.
Schmidt, Chester J., Chicago, Ill.
Schregardus, William F., St. Louis, Mo.
Schwartz, David L., New York, N. Y.
Shield, John, Montreal, Que.
Shields, James R., (Member), Toronto, Ont.
Siedler, Charles P., New York, N. Y.
Skarbovik, Bjarne J., Mexico, D. F., Mex.
Stavoli, Francisco, J., Mexico, D. F. Mex.
Stewart, Spencer W., (Fellow), New York, N. Y.
Strieby, Maurice D., (Member), New York, N. Y.
Talbot, John C., New York, N. Y.
Taylor, William O., Montreal, Que.
Thelin, Victor E., (Member), Boston, Mass.
Tisne, Roland D., San Francisco, Cal.
Van Allen, Lansing E., Schenectady, N. Y.
Van Meter, Joseph LeR., (Member), New York, N. Y.
Vipond, William S., (Member), Montreal, Que.
Wallbrecht, Claud A., New York, N. Y.
Wehle, Arthur H., Jamaica, N. Y.
Williams, Charles E., Seattle, Wash.
Wintersteene, Guy H., Alliance, Ohio
Total 94.

Foreign

Carradus, Thomas W., (Member), Manchester, Eng.
Childs, Henry W., Kaiapio, New Zealand
Coll, Ernest A., San Juan, P. R.
Hartmann, Julius F. G. P., (Fellow), Copenhagen, Denmark
Hoseason, Donald B., Trafford Park, Manchester, Eng.
Mollerhoj, Johannes S., Copenhagen, Denmark
Mukerjie, U. N., Patna, India
Nagashima, Yasunosuke, Hamamatsu City, Shizuoka-ken, Japan
Soldini, Mario G., Milan, Italy
Takai, Ryotaro, Marunouchi, Tokyo, Japan
Walker, Harry W., Christchurch, N. Z.
Young, Henry P., (Member), London, Eng.
Total 12.

STUDENTS ENROLLED, JUNE 29, 1922

15171 Lowe, Ralph R., Lafayette College
15172 Lyman, Walter J., Carnegie Inst. of Tech.
15173 Clymer, Gale B., Ohio Northern Univ.
15174 Whitescarver, Charles K., Virginia Polytechnic Institute.
15175 Conboy, Richard L., Clarkson College of Technology
15176 Moser, Matthew X., Marquette Univ.
15177 Joachim, Paul E., Carnegie Inst. of Tech.
15178 Lockwood, Henry V., New York Electrical School
15179 Andrews, William S., Carnegie Inst. of Tech.
15180 Newby, Neal D., Kansas University
15181 Howerth, Dwight G., Cornell University
15182 Brown, Ralph E., Northeastern College, School of Engg.
15183 Chase, Charles S., Northeastern College, School of Engg.
15184 Pinckert, Walter F., Tri-State Coll. of Engg.
15185 Blanton, William B., Virginia Poly. Inst.
15186 Farmer, G. Everett, Mass. Institute of Tech.
15187 Fuller, Norman K., Pratt Institute
15188 Iams, Harry S., Pennsylvania State College
15189 Estcourt, Vivian F., Stanford University
15190 Hennessy, James J., Lewis Institute
15191 Gillespie, George, Lewis Institute
15192 Jirousek, Miroslac, Lewis Institute
15193 Bailey, Edgar E., Tri-State College of Engg.
15194 Wagner, B. S., University of Cincinnati

15195 Cooney, William H., Worcester Poly. Inst.
15196 Chatham, Clyde L., Mass. Institute of Tech.
15197 Ross, Walter S., Mass. Institute of Tech.
15198 Pabst, William, Brooklyn Polytechnic Inst.
15199 Calvert, Albert, Mass. Institute of Tech.
15200 Cotter, James L., Pennsylvania State Coll.
15201 Marthens, Arthur S., Carnegie Institute of Technology.
15202 Evenson, Harold O., Marquette University
15203 DePrato, Edwin W., Rice Institute
15204 McKean Hugh R., Rice Institute
15205 Cox, Joseph H., Mass. Institute of Tech.
15206 Erickson, George L., Mass. Inst. of Tech.
15207 Erickson, Carl E., Tri-State College of Engg.
15208 McCarthy, Jeremiah J., Lowell Institute
15209 Ryan, Paul A., Mass. Institute of Tech.
15210 Johns, Frank J., Tri-State College of Engg.
15211 Wood, Daniel S., Jr., Sheffield Scientific School
15212 Augur, J. Minott, Yale University
15213 Henry, Frederick J., Purdue University
15214 Vichules, John J., Purdue University
15215 Rhinehart, Robert J., Purdue University
15216 Lubker, Alvin C., Purdue University
15217 Welch, Joseph F., Purdue University
15218 Smith, George L., Purdue University
15219 Stoddard, George A., Wentworth Institute
15220 Odquist, Ernst H. T., Stevens Inst. of Tech.
15221 West, Robert R., Penn. State College
15222 Rankin, William C., Penn. State College
15223 Hieronymus, Rex E., University of Colo.
15224 Nerses, K., Wentworth Institute
15225 Walker, George A., Worcester Poly. Inst.
15226 Parnin, John R., Purdue University
15227 Murphy, Joseph B., Marquette University
15228 Degentesh, Henry E., Marquette University
15229 Brazel, Harry, Marquette University
15230 Cane, Stanley J., Marquette University
15231 Phelps, George E., Marquette University
15232 Chaffee, Joseph G., Mass. Inst. of Tech.
15233 Sleeman, Harold P., Carnegie Inst. of Tech.
15234 Blowers, William E., Purdue University
15235 Bennett, Richard H., Jr., Emory Univ.
15236 Van Iderstine, William W., Wentworth Inst.
15237 Scheppach, Maximilian A., Penn. State Coll.
15238 Pritchard, Newman L., Stevens Institute
15239 Daly, Ezra, Rensselaer Polytechnic Inst.
15240 Crosby, Paul W., Mass. Institute of Tech.
15241 Van Keuren, Robert G., Wentworth Inst.
15242 Cooley, Austin G., Mass. Institute of Tech.
15243 Connon, William D., University of Maine
15244 Morhun, Joseph H., Toronto Central Technical School
15245 Miner, Erle S., University of Kansas
15246 Krieg, Edwin H., Cornell University
15247 Lawrence Joseph D., Jr., Univ. of Penna.
15248 Crowley, Harold F., Wentworth Inst.
15249 Yaeger, Albert A., Jr., Univ. of Michigan
15250 Schmitz, Richard C., Univ. of Michigan
15251 Blood, George B., Wentworth Institute
15252 Vilett, Everet W., Mass. Institute of Tech.
15253 Paul, Ralph D., Worcester Poly. Institute
15254 Penniman, George F., Worcester Poly. Inst.
15255 Meyer, Lester J., Marquette University
16256 Chu, S. P., Mass. Institute of Technology
15257 Andrich, John, University of Colorado
15258 Kelly, John W., University of Colorado
15259 Smith, Guerdon W., University of Colorado
15260 Culverwell, Ernest A., Univ. of Colorado
15261 Sullivan, Edward M., The Catholic University of America.
15262 Goughnour, Ward C., Carnegie Inst. of Tech.
15263 Jackson, Dana E., Jr., Wentworth Inst.
15264 Tsui, John H. H., Worcester Poly. Institute
15265 Zimmerman, James H., Penn. State College
15266 Festner, Robert H., Stevens Inst. of Tech.
15267 Bailey, Ellsworth B., Univ. of Washington
15268 Gershen, Julius C., Carnegie Inst. of Tech.
15269 Smith, Fred B., Wentworth Institute
15270 Mathes, Richard E., University of Minn.
15271 Spencer, Hugh H. Mass Inst. of Technology
15272 Flory, Carl L., Mass. Inst. of Technology
15273 Sears, Edward F., Toronto Central Technical School
15274 Pruzick, Albert A., Brooklyn Poly. Inst.
15275 Lefferts, Benjamin B., Brooklyn Poly. Inst.
15276 Rosner, Herman, Brooklyn Poly. Inst.
15277 Selman, Milton, Brooklyn Poly. Inst.
15278 Webster, Fullerton D., Mass. Inst. of Tech.
15279 Lundborg, Carl J., Mass. Institute of Tech.
15280 Schneider, Elmer T., Wentworth Institute
15281 Smith Banks W., Jr., N. Y. Electrical Sch.
15282 Truve, Carl E., Stevens, Inst. of Tech.
15283 Kimball, Richard L., Worcester Poly. Inst.
15284 Weis, Charles L., Jr., Mass. Inst. of Tech.
15285 Burritt, Leslie D., Stevens Inst. of Tech.
15286 Adam, Louis G., Univ. of Wisconsin
15287 Porter, William A., University of Colorado
15288 Mellors, Tom, University of Colorado
15289 Knight, Donald P., Mass. Inst. of Tech.
15290 Sanborn, Gordon P., Wentworth Institute
15291 Tarleton, Delmar H., State Coll. of Wash.
15292 Goetchius, Rodney M., Mass. Inst. of Tech.
15293 Pettengill, John B., Wentworth Institute.
15294 Gilligan, Charles F., Wentworth Institute
15295 Wise, Arthur G., The Ohio State Univ.
15296 Varney, Clifford F., N. Y. Electrical Sch.
15297 Baum, Sydney H., Cooper Union
15298 Spooner, Warren, Stevens Inst. of Tech.
15299 Flagg, Paul M., University of Washington
15300 Patten, Maurice W., University of Wash.
15301 Llewellyn, Fred B., Stevens Inst. of Tech.
15302 Wilcox, John C., Stevens Inst. of Tech.
15303 Christie, Robert L., Stevens Inst. of Tech.
15304 Cota, Florencio N., Stanford University
15305 Thompson, John H., Mass. Inst. of Tech.
15306 Paulison, William L., Jr., Stevens Institute of Technology
15307 Norman, Albert M., Tri-State College of Engineering
15308 Dibelo, Vincent J., New York Electrical School

Total 138

OFFICERS OF A. I. E. E. 1921-1922

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William McClellan

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A. I. E. E. COMMITTEES

(A list of the personnel of Institute committees may be found in the June issue of the Journal, and a list of the new committees to be appointed in August will be published in the September issue.)

GENERAL STANDING COMMITTEES AND CHAIRMEN

Executive, William McClellan
Finance, L. F. Morehouse
Meetings and Papers, E. E. F. Creighton
Publication, A. S. McAllister
Coordination of Institute Activities, W. I. Slichter
Board of Examiners, H. H. Norris
Sections, A. W. Berresford
Student Branches, C. Francis Harding
Membership, E. H. Martindale
Headquarters, W. A. Del Mar
Law, H. H. Barnes, Jr.
Public Policy, H. W. Buck
Code of Principles of Professional Conduct, C. A. Adams
Safety Codes, H. B. Gear
Standards, Harold Pender
Edison Medal, C. A. Adams
Research, F. B. Jewett

TECHNICAL COMMITTEES AND CHAIRMEN

Educational, C. E. Magnusson
Electrical Machinery, B. A. Behrend
Electrochemistry and Electrometallurgy, Lawrence Addicks.
Electrophysics, F. W. Peek, Jr.
Industrial and Domestic Power, W. C. Yates
Instruments and Measurements, F. V. Magalhaes
Iron and Steel Industry, E. S. Jefferies
Lighting and Illumination, G. H. Stickney
Marine, Arthur Parker
Mines, Graham Bright
Power Stations, R. F. Schuchardt
Protective Devices, H. R. Woodrow
Telegraphy and Telephony, Donald McNicol
Traction and Transportation, H. M. Brinckerhoff
Transmission and Distribution, Edward B. Meyer

A. I. E. E. REPRESENTATION

(The Institute is represented on the following bodies; the names of the representatives may be found in the June issue of the Journal and will be published again in the September issue.)

Council of the American Association for the Advancement of Science
American Bureau of Welding
American Committee on Electrolysis
American Engineering Council of the Federated American Engineering Societies
American Engineering Standards Committee
Board of Trustees, United Engineering Society
Engineering Foundation Board
Franco-American Engineering Committee
John Fritz Medal Board of Award
Library Board, United Engineering Society
Electrical Committee, National Fire Protection Association
Engineering Division, National Research Council
U. S. National Committee of the International Illumination Commission
U. S. National Committee of the International Electrotechnical Commission
Commission of Washington Award

A. I. E. E. SECTIONS AND BRANCHES

A complete list of the 46 Sections and the 68 Student Branches of the Institute with the names of the chairmen and secretaries, may be found in the June issue and will be published again in the September issue.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGS AND OTHER TRADE PUBLICATIONS

Mailed to interested readers by issuing companies.

Distribution Transformers.—Bulletin 1109. Describes the various types of distribution transformers produced by the Allis-Chalmers Co., Milwaukee.

Resistance Thermometers.—Catalog. Outlines the theory of resistance thermometry, types of instruments and merits of each. Brown Instrument Co., Philadelphia.

Cedar Poles.—"Butt Treatment of Cedar Poles." Booklet, 20 pp. A treatise on modern development in the preservation of cedar pole timber. Naugle Pole & Tie Co., Chicago.

Automatic Sirens.—Bulletin, 12 pp. Describes "Heath" automatic sirens for use as signalling systems in industrial plants, as fire alarms, etc. Heath Engineering Laboratories, San Francisco.

Monel Metal.—Catalog No. 10, 8 pp. Describes "Elalco Monel Metal," a natural nickel-copper alloy containing 67% or more pure nickel. The Electrical Alloy Co., Morristown, N. J.

Electric Furnaces.—Booklet, 22 pp. Describes "Greaves-Etchells" furnaces for melting, refining and superheating of iron and steel or alloys. Electric Furnace Construction Co., Philadelphia.

Automatic Train Control.—Booklet, 62 pp. Describes the "G-R-S" train control systems to enforce obedience to fixed signals or speed restrictions. General Railway Signal Co., Rochester, N. Y.

Hydraulic Equipment.—Booklet, 16 pp., "Kern River Number Three Plant of the Southern California Edison Company." Describes the hydroelectric apparatus and accessory equipment installed in this plant. The Pelton Water Wheel Co., San Francisco.

Polyphase Transformers.—Bulletin 2015, 24 pp. Describes a new polyphase transformer and includes connection and test diagrams not heretofore readily available, and therefore valuable to engineers and operators, as well as to students and instructors. Pittsburgh Transformer Co., Pittsburgh.

Pulverized Fuel.—Booklet, 16 pp., "Powdered Coal Application to Four 2640 hp. Boilers." Describes installation at the River Rouge plant of the Ford Motor Company. It includes the operating results of the plant, which has been in operation over a year. Combustion Engineering Corporation, Broad St., New York.

Radio Telephone Receivers.—Bulletin 20, 4 pp. Describes "Universal" Type Radio Telephone Receivers. It is claimed that excellent results are obtained on both crystal and vacuum tube sets and that the receivers are also particularly well adapted for use with loud speaking units. Roller-Smith Co., 12 Park Place, New York.

Cranes and Hoists.—Condensed General Catalog 28, 32 pp. and "D" Hoist Catalog, 43, 16 pp. Describe a line of electric traveling cranes, bridge and gantry cranes, hand power cranes—all types; pillar and jib cranes and derricks, electric hoists for all purposes, air hoists, trolleys, overhead tracks, air jacks, turntables and transfer tables. Northern Engineering Works, Detroit.

Automatic Control Switches.—Bulletin B, 4 pp. Describes the "Mercoid" switch, which consists of a gravity operated mercury device actuated by a Bourdon Tube arranged to open or close an electrical circuit at predetermined pressures. The switch can be furnished in any combination or series of combinations of various designs that may be required. The Federal Gauge Co., Chicago.

Mica.—Serial No. 2357, 46 pp., by Oliver Bowles. Consists of the reports of investigations into the mica industry. Describes the various chemical and physical properties of mica, gives figures as to production and consumption uses, grades and specifications, mining and manufacturing processes, lists of producers and dealers. Copies may be obtained upon application to the A. I. E. E., 33 West 39th Street, New York, or to the Bureau of Mines, Washington, D. C.

Electric Steam Boiler.—Booklet, 10 pp. Describes the "Electro" steam generator developed by F. T. Kaelin, Chief Engineer, Shawinigan Water & Power Company. It is an apparatus for generating steam in any required quantity at any specified pressure by means of alternating current, which is led directly into the water to be evaporated. A number of large installations are in successful operation, including one of 20,000 kw., capable of raising 60,000 pounds of steam per hour. The Electric Furnace Construction Company, Philadelphia, are in charge of its development in the United States.

CHANGES IN THE INDUSTRY; NEW APPARATUS

Century Electric Company, St. Louis.—A sales office has been opened at Room 401 Alaska Bldg., Seattle, Wash.

Condit Electrical Manufacturing Company, Boston.—This firm has acquired exclusive sales rights in the temperature—indicating semaphore apparatus for transformers of the Standard Thermometer Company.

Dingle-Clark Company, Cleveland.—Power plant equipment sales engineers. A new office has been opened in Cincinnati at 605 Mercantile Library Building, in charge of C. G. Tarkington.

Lightning Arresters.—A new type of direct-current electrolytic lightning arresters known as "Type AR" for car or station use on railway, power and lighting circuits, has been developed by the Westinghouse Electric & Mfg. Co., East Pittsburgh.

Wilson Welder & Metals Company, Inc., New York.—The King-Knight Company, Underwood Bldg., San Francisco, have been appointed exclusive sales representatives in Central and Northern California for Wilson Plastic-Arc Welding Machines and "Color-Tipt" Metals.

Oil Circuit Breaker.—The Condit Electrical Manufacturing Company, Boston, has developed a new type "*O*-1" circuit breaker, particularly adaptable to outdoor service. It may be installed on almost any mounting, either pole or framework, and is furnished automatic or non-automatic, as desired. The "*O*-1" is built for 15,000 or 25,000 volts, up to and including 600 amperes.

Westinghouse High Voltage Insulator Company.—The business of the Pittsburgh High Voltage Insulator Company will be carried on in the future under the name of the Westinghouse High Voltage Insulator Company according to an announcement made by C. M. Semler, General Manager. This change in name, which was voted by the company's stockholders, does not affect the management or method of carrying on the business of the firm.

Economy Fuse & Manufacturing Company, Chicago.—Announcement is made of the appointment of Mr. Chas. H. Bluske as District Sales Manager of the Los Angeles office at 1304 Maltman Avenue. Mr. Bluske was formerly connected with the Pacific States Electric Company of Los Angeles.

The Pittsburgh sales office has been moved from 2223 Farmers Bank Building to 1006 Peoples Bank Building, at 4th Avenue & Wood Street.


Use
KERITE
DAYS KERITE
for
signal
service
the Dictionary says:
signal (sig´nạl), a. Distinguished from the ordinary; extraordinary; conspicuous.
KERITE INSULATED WIRE & CABLE COMPANY
NEW YORK CHICAGO

Steadfast Service

STAUNCH as the sturdy "windjammer." laden to the water line, holding her steadfast course through tossing seas, the CONDIT K-1 *Air Circuit Breaker* keeps your machines on the line through every fluctuation of normal load.

Yet in time of tempest even the stoutest ship must shorten sail and ride before the storm. So with your circuits.

When dangerous overloads threaten your equipment the positive dependable operation of the K-1 affords sure protection.

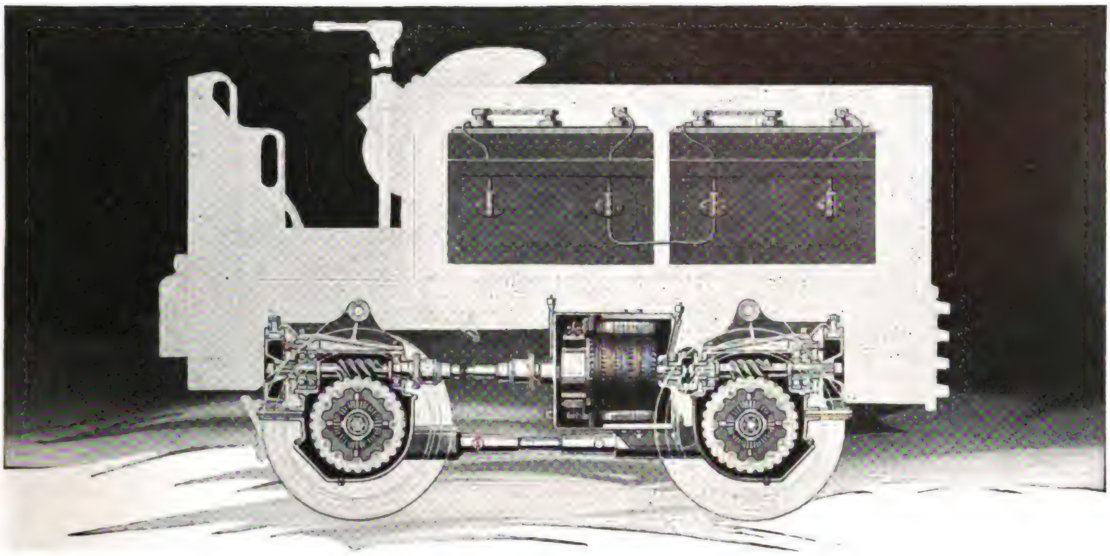
CONDIT
ELECTRICAL MFG. CO.
Boston 27, Mass.
Manufacturers of Electrical Protective Devices

Northern Electric Company, Ltd.
Sole Distributor for the Dominion of Canada

K-1 Air Circuit Breaker

SPECIFICATIONS: 1, 2, 3 or 4 Pole; Rear Connected, Manually or Electrically operated; 100 to 8,000 Amperes; 650 Volts D. C.; Supplied with all usual accessories.

CONDIT



Ball Bearings on Industrial Trucks

Mean Decreased Maintenance and More Ton-Miles

OWNERS of industrial trucks are primarily interested in low maintenance costs and in obtaining the greatest number of ton-miles from a given battery charge.

Both of these requirements can be met when deep-groove ball bearings, as made by the Hess-Bright Manufacturing Company, are used on the motor, driving members and wheels.

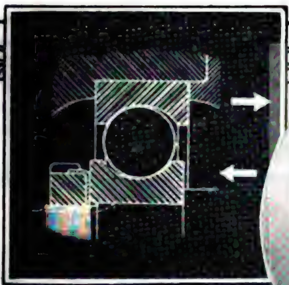
As this type of bearing shows no appreciable wear there is no need for bearing take-up and adjustment. Stripped armatures, due to dropped shafts, are impossible as are also the common troubles due to wear in the driving and differential gearing.

Furthermore, there is no unnecessary drain on the battery to overcome needless friction. This energy which plain bearings waste is available in the form of additional ton-miles when ball bearings are used.

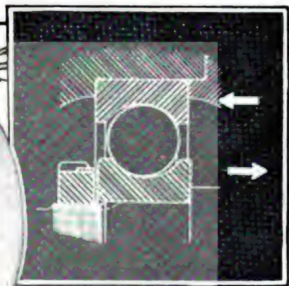
Let our engineering department co-operate with you in adapting your trucks to these market demands.

THE HESS-BRIGHT MANUFACTURING COMPANY

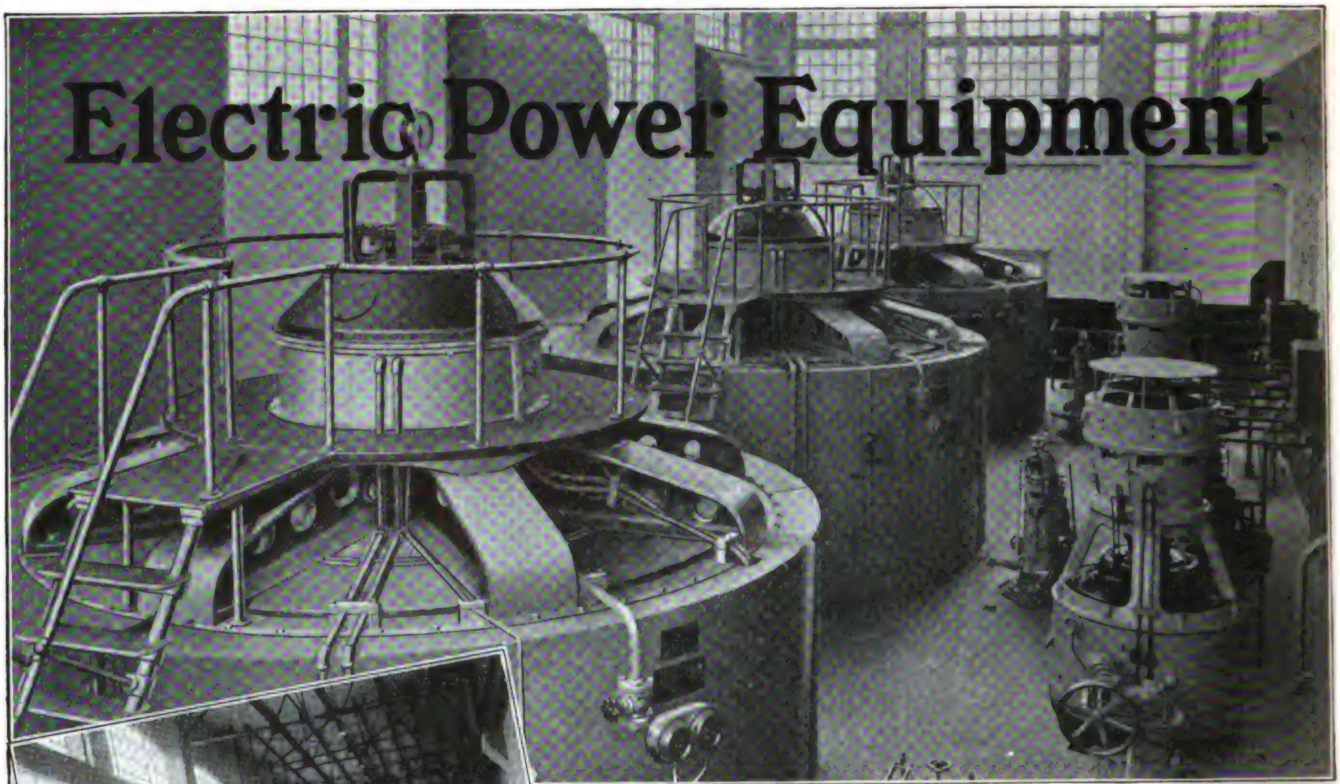
773 **Supervised by SKF INDUSTRIES, INC., 165 Broadway, New York City**

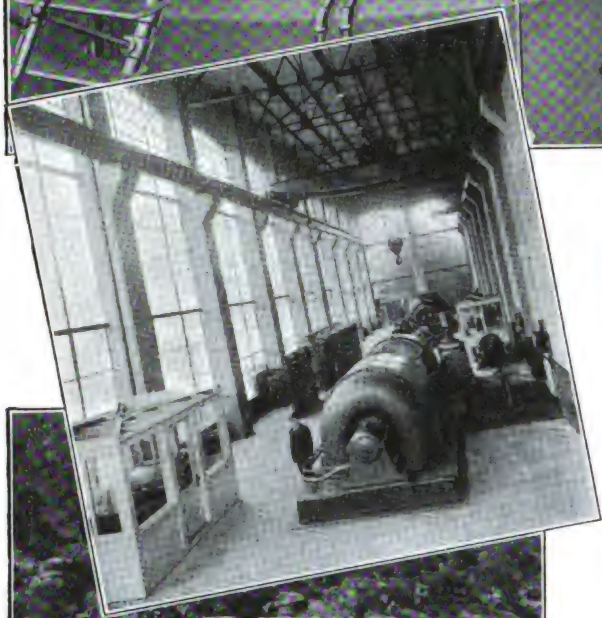


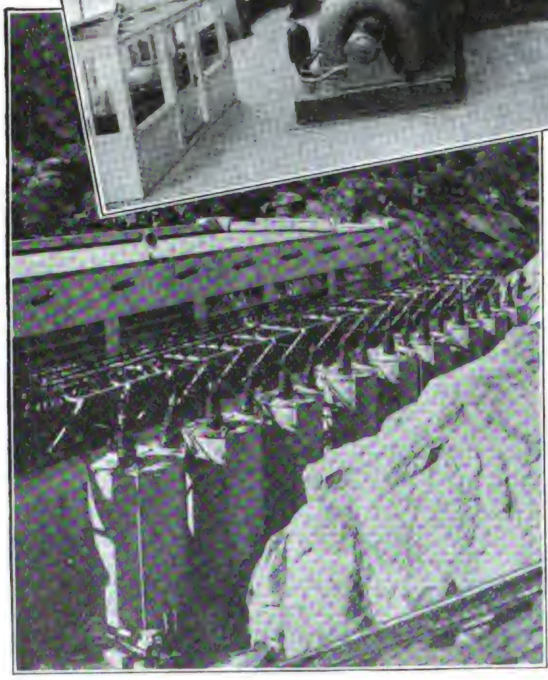
Races displaced to show DEEP-GROOVE bearing carrying maximum end thrust in a forward direction.



Races displaced to show THE SAME bearing carrying maximum thrust in reverse direction.







FOR the power plant, complete equipment, "from prime mover to switchboard" is built by the Allis-Chalmers organization. This includes all types of prime movers—steam turbines, hydraulic turbines, steam, gas and oil engines, together with complete electrical equipment. Condensers of all types, pumps, air compressors and many other auxiliaries are also supplied. Allis-Chalmers equipment is used in plants of all sizes, and includes some of the largest power units ever built.

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Electrical Machinery
Steam Turbines
Steam Engines
Gas and Oil Engines
Hydraulic Turbines
Crushing and Cement Machinery
Mining Machinery
Agricultural Machinery

Flour and Saw Mill Machinery
Power Transmission Machinery
Pumping Engines
Centrifugal Pumps
Steam and Electric Hoists
Air Compressors-Air Brakes
Condensers

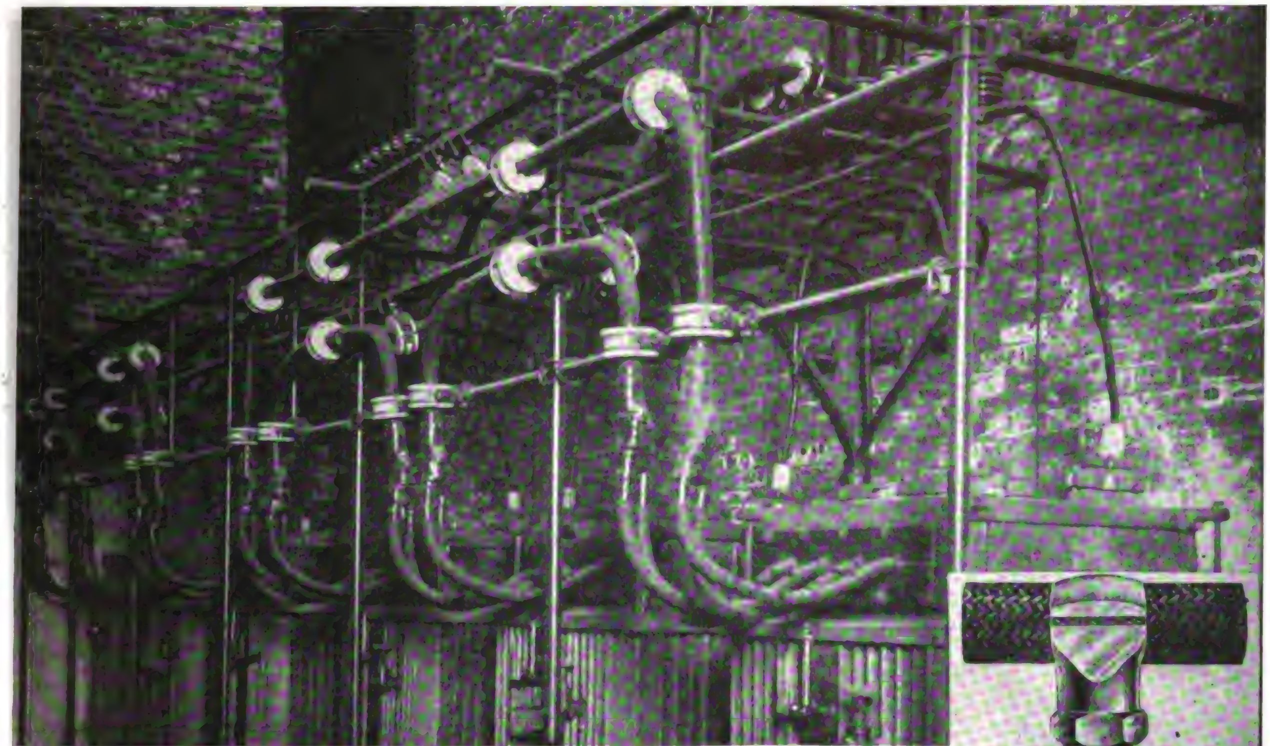
ALLIS-CHALMERS

MILWAUKEE, WIS. U. S. A.

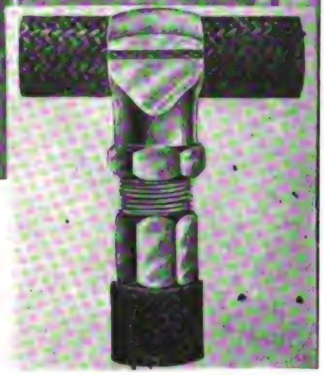
DOSSERT CONNECTORS

IN

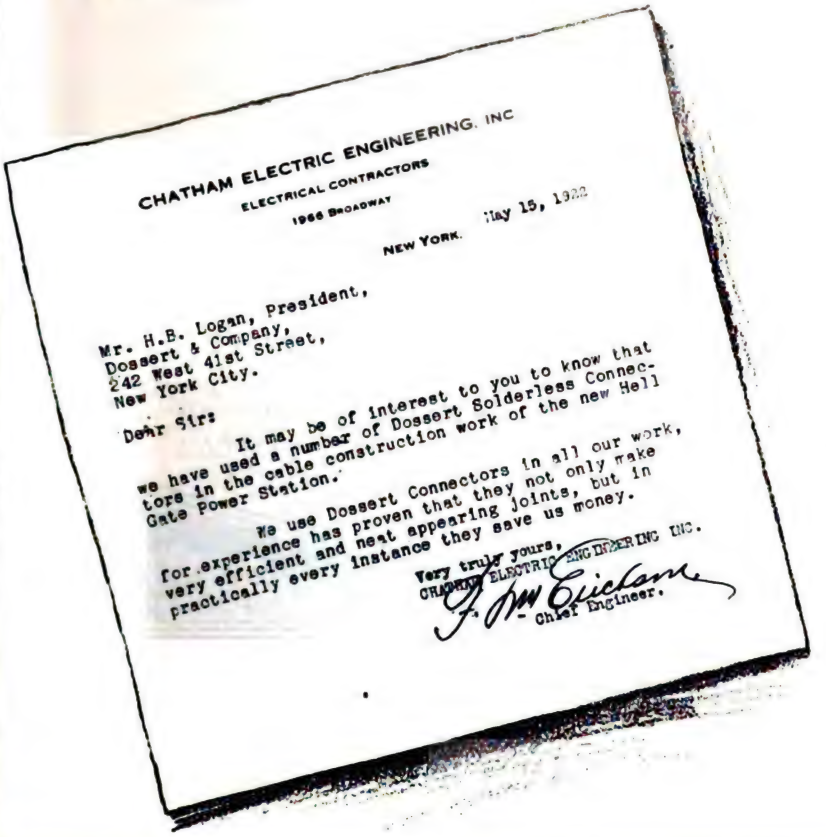
HELL GATE STATION



The above shows Dossert Cable Tap Connectors in the Hell Gate Station, connecting the one million circular mils, 2,300 volt bus cables to the Transformers



DOSSERT CABLE
TAP



CHATHAM ELECTRIC ENGINEERING, INC
ELECTRICAL CONTRACTORS
1966 BROADWAY
NEW YORK. May 15, 1922

Mr. H.B. Logan, President,
Dossert & Company,
242 West 41st Street,
New York City.

Dear Sir:

It may be of interest to you to know that we have used a number of Dossert Solderless Connectors in the cable construction work of the new Hell Gate Power Station.

We use Dossert Connectors in all our work, for experience has proven that they not only make very efficient and neat appearing joints, but in practically every instance they save us money.

Very truly yours,
CHATHAM ELECTRIC ENGINEERING INC.
F. Wm Eickam
Chief Engineer.

Dossert Connectors need no solder, make a perfect connection and cannot jar loose. The tightening of a few nuts is all that is required to make a satisfying permanent connection.

Send for Catalog Fifteen

DOSSERT & CO.

H. B. LOGAN, President

242 West 41st Street, New York

"P & H" Guaranteed Penetration Process Poles Stand Your Own Test

The *metal disc* countersunk on the butt-end of every pole is your assurance of the guaranteed half inch uniform penetration.

The *written guarantee* issued with every shipment of poles is your assurance of money back on every pole that fails to show the guaranteed half inch depth of preservative.

Your own test, of these poles, is your means of assurance of an 100 per-cent job of Butt-Treatment.

Accept no substitute process
Insist upon the "P & H" Guaranteed

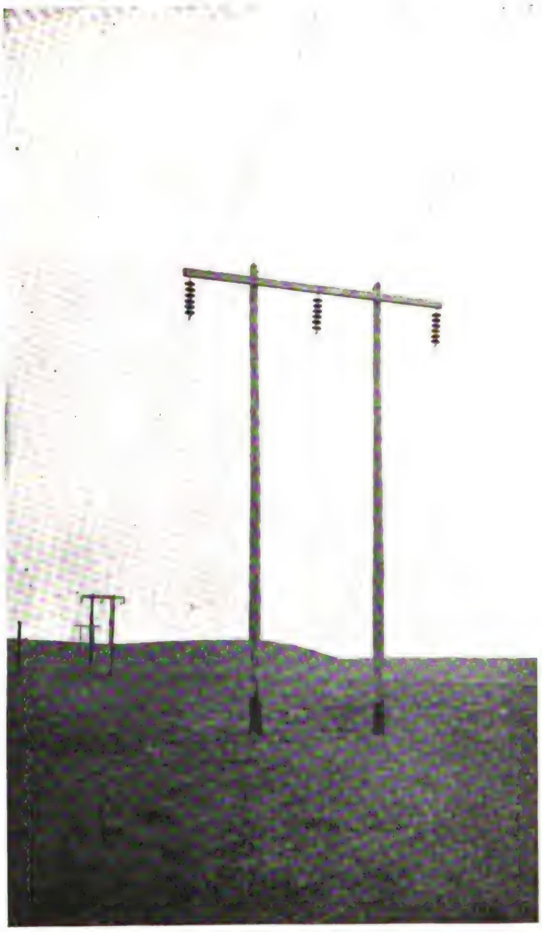
WE produce and sell treated and untreated Northern White and Western Red Cedar Poles;—we can give you any form of Butt-Treatment;—and we are the originators of the Guaranteed Penetration Process—the "P & H".

Our Pamphlet "Butt-Treating Cedar Poles at the Page & Hill Plant" will tell you all about it.

PAGE AND HILL CO.

MINNEAPOLIS, MINN.

50 Church St., New York, N. Y.
1111 Carter Bldg., Houston, Tex.
717 Bryant Bldg., Kansas City, Mo.
311 Sumpter Bldg., Dallas, Tex.
19 S. La Salle St., Chicago, Ill.
1416 Starks, Bldg., Louisville, Ky.



Type "H"

The Western Red Cedar withstanding the fierce storms; sleet and wind can-*struction,* for it combines two, and sometimes three

Giants of

Sold

THE VALENTINE-

914 Security Bldg.,

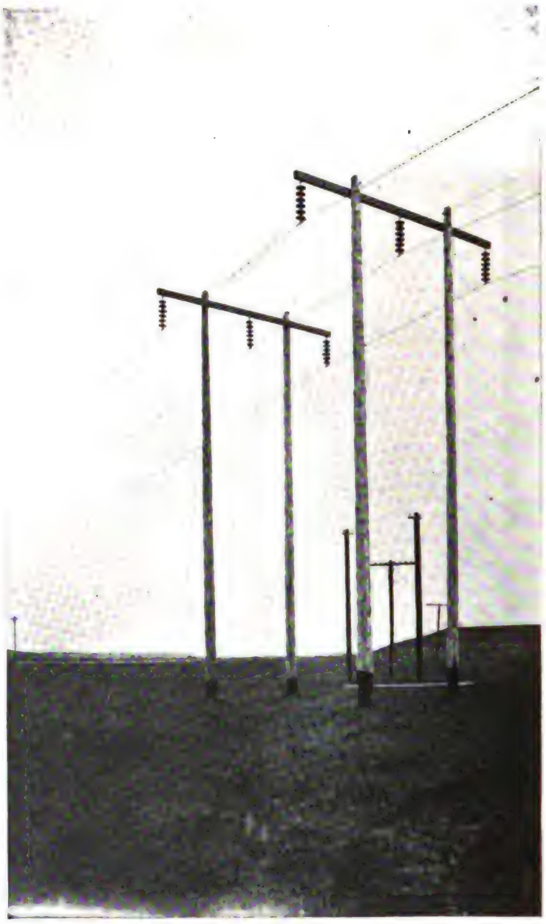
NEW YORK
BOSTON
PHILADELPHIA

Main

MINNESOTA

We will preserve the butts of your Poles with a genuine coal tar distillate. There are many methods and specifications but the one big idea is to make the butt end of the Pole last as long as the top and mid-section.

The secret of wood preservation is simple: Poison your wood so it will not be attacked by fungi at the ground line by using a high boiling oil of coal tar. This will forever hold the poison and not leach out. Results are permanent if properly applied.



Construction

Tree grows to maturity
onslaughts of innumerable
not injure *Type "H" Con-*
the strength of at least
Poles.

Transmission

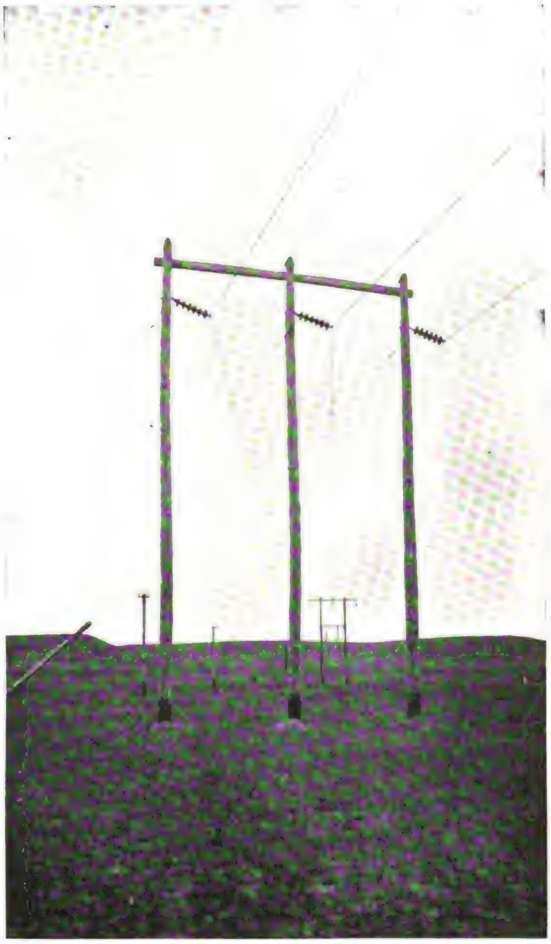
By

CLARK COMPANY

Minneapolis, Minn.

Yard
TRANSFER

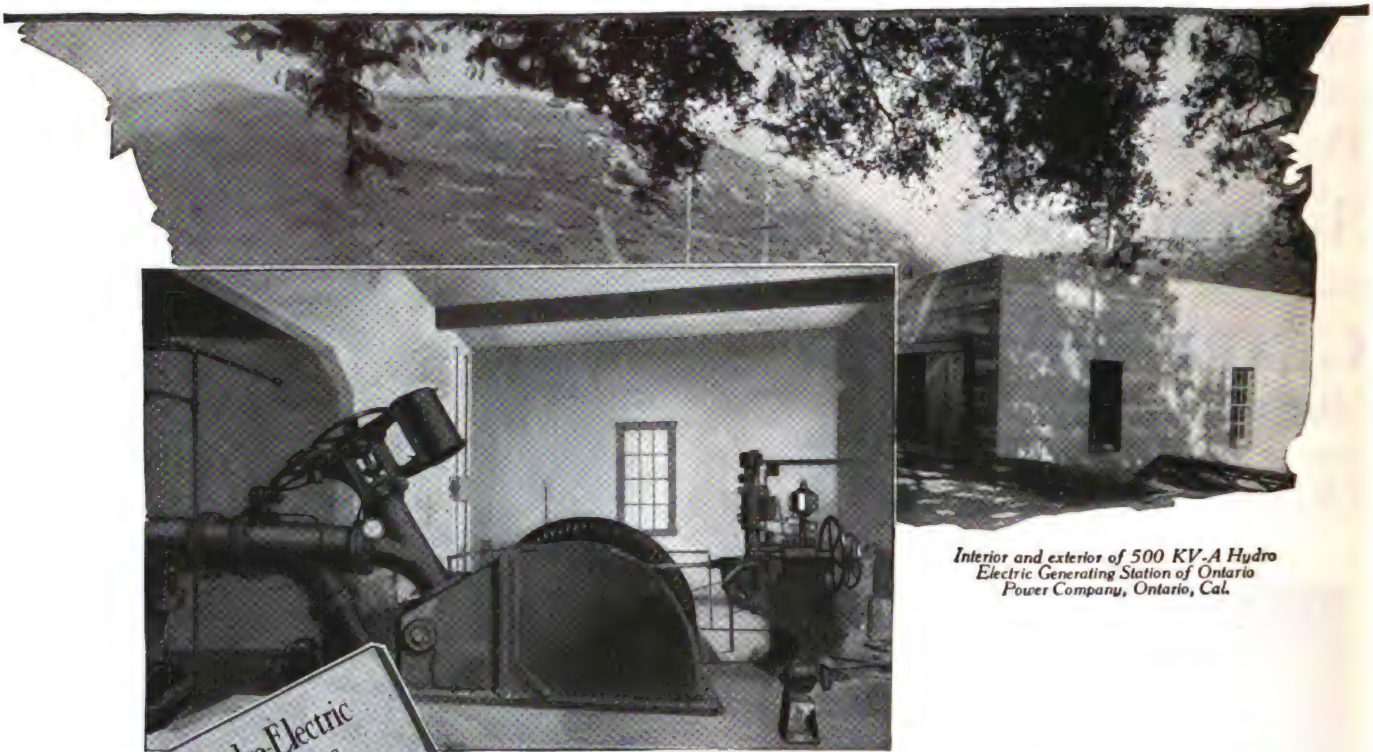
CHICAGO
TOLEDO
SPOKANE



All the Standard Pole Butt Preservation Specifications that we furnish are worthy of careful consideration. Specification "AA" is desirable for light types of construction. Specifications "A", "B" and the Pentrex $\frac{3}{8}''$ or $\frac{1}{2}''$ Guaranteed Penetration will all add many years of service to a Cedar Pole.

We are well equipped to do this work; remember there is a difference between a "treated" Pole and a Pole which has been PRESERVED at the butt end.

Proper conservation, or the development of ALL sources of water power regardless of size, or location, is greatly aided by automatic station equipment



Interior and exterior of 500 KV-A Hydro Electric Generating Station of Ontario Power Company, Ontario, Cal.

This bulletin on Automatic Hydroelectric Generating Stations awaits the call of every man interested. Send for it.

Putting Every Stream to Work

DUE to the advent of General Electric Automatic Hydro-Electric Stations, many power sites have been developed that would have been impractical for manually controlled stations.

The automatically controlled station allows large power systems to take advantage, safely and economically, of undeveloped sites where the head is small or intermittent, which are inaccessibly located, and where trained operators are unavailable.

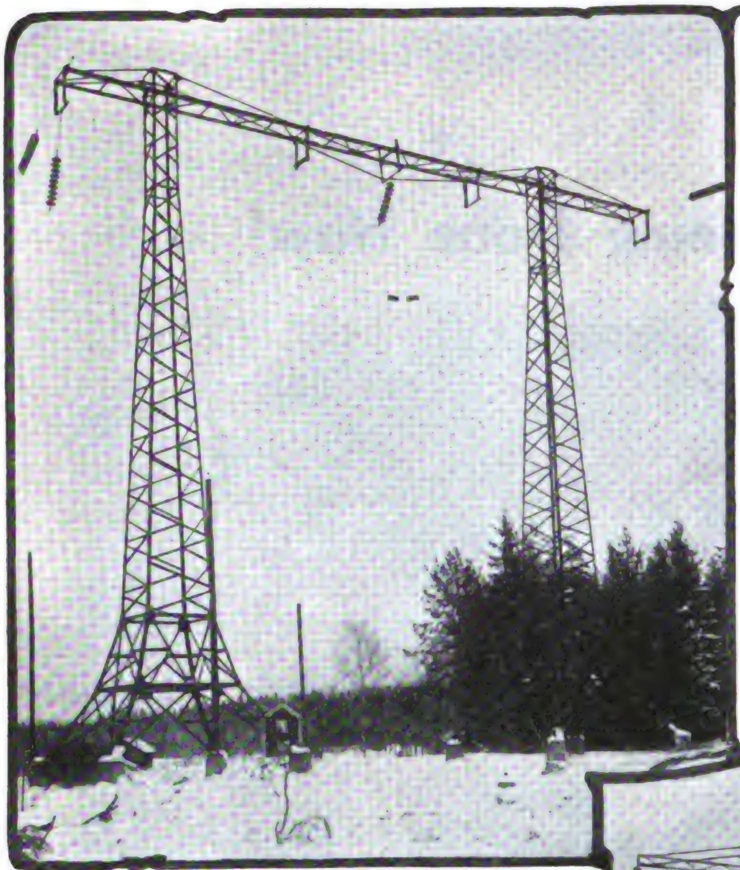
This type of station, like other types of G-E Automatic Stations—Synchronous Converter, Synchronous Condenser, etc., is valuable for several purposes; to provide extra power to carry peak loads on a system, to furnish a small but steady amount of power to a large system, or to furnish power for individual industrial installations.

General Electric Company

General Office Schenectady, N.Y.

Sales Offices in all large cities

54C-54

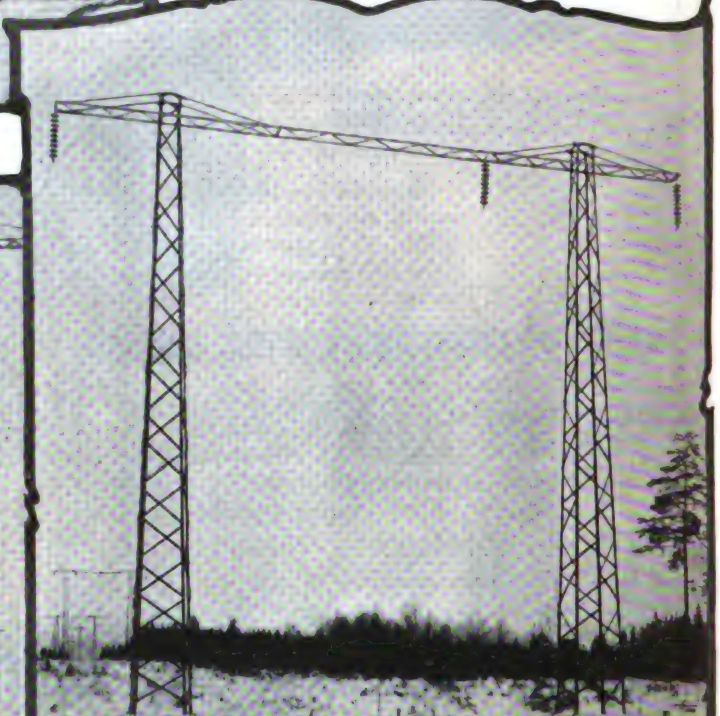


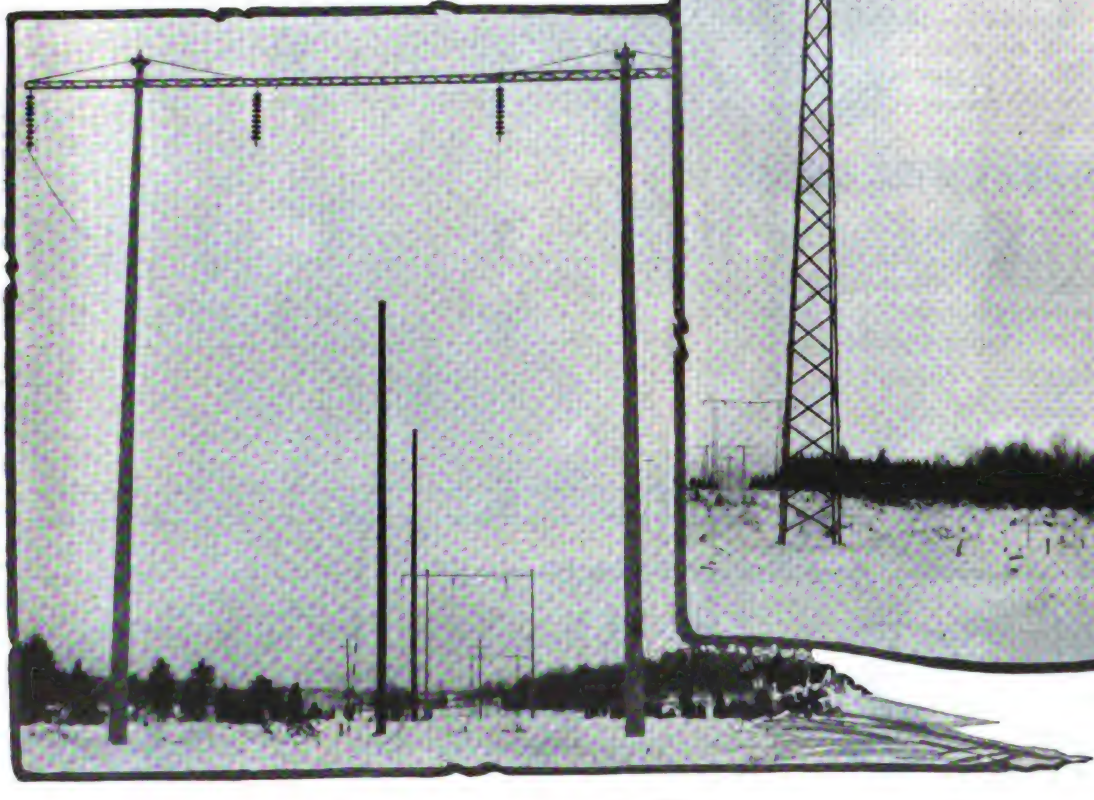
O-B Insulators
and
The One Minute

A prominent new business manager said, in an Electrical World article: "the average customer will remember one minute's interruption longer than the other 525,599 minutes in the year."

Thousands and thousands of O-B Insulators in all parts of the world are helping central stations deliver 525,600 minutes of service every year.

The photographs are of the 132,000 volt line of the Royal Board of Waterfalls, Sweden. Twenty-seven thousand O-B Insulators are used on this line.





The Ohio Brass Co.
Mansfield, Ohio, U.S.A.

New York Philadelphia Pittsburgh Charleston, W Va. Chicago Los Angeles San Francisco Paris, France

Products: Trolley Material, Rail Bonds, Electric Railway Car Equipment, High Tension Porcelain Insulators, Third Rail Insulators

MOLONEY TRANSFORMERS

FOR POWER SERVICE

Moloney Power Transformers are designed and built to give the maximum service demanded of transformers of this kind.

Low Densities in iron and copper, Large Cooling Surfaces, Liberal Insulation, and Great Mechanical Strength are the well-known features of Moloney Power Transformers which have made them so thoroughly satisfactory in this field of service.

Send for the new Moloney Catalog!

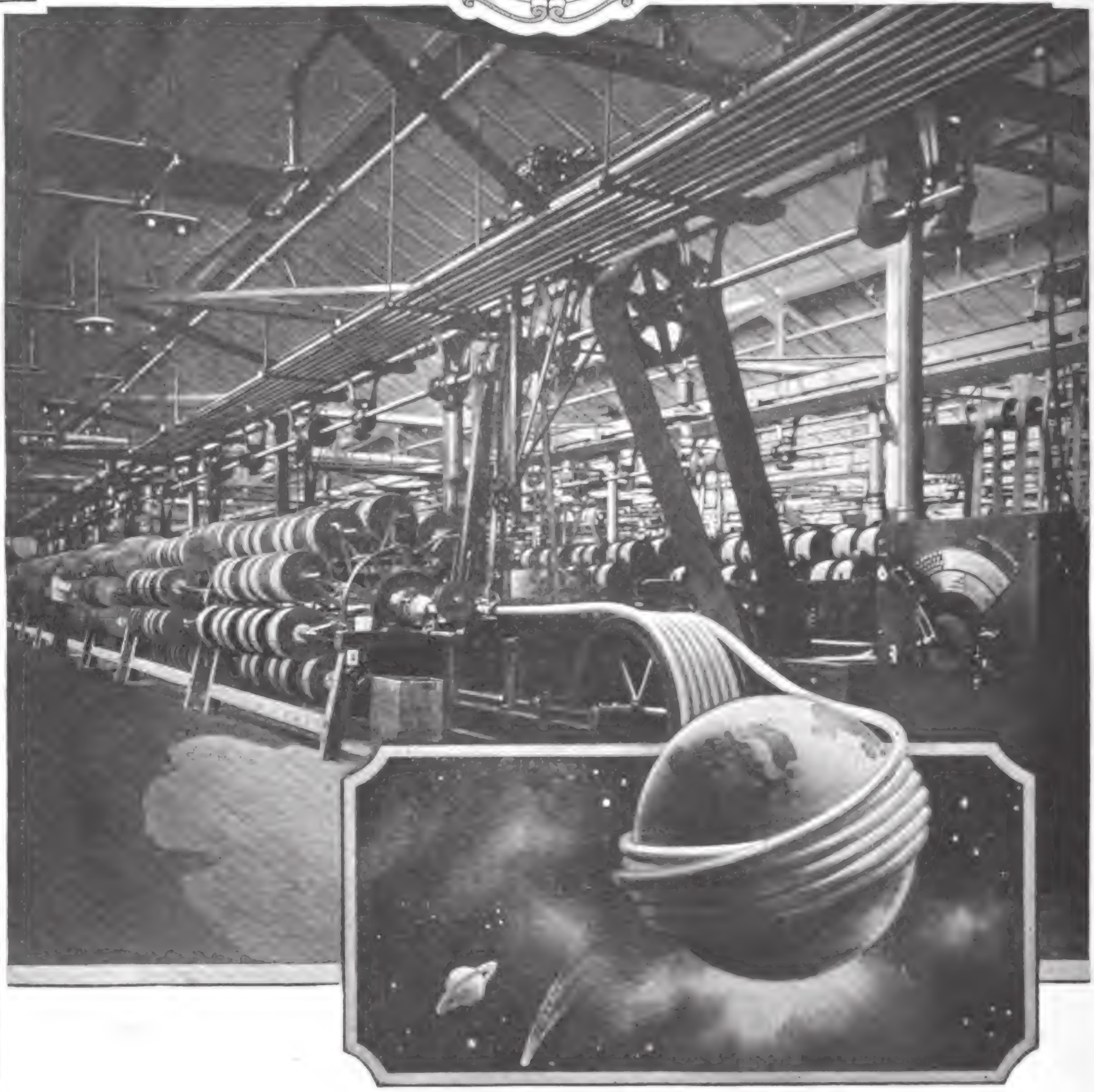
Moloney Electric Co.

Manufacturers of **TRANSFORMERS EXCLUSIVELY**

Factories:

St. Louis, Mo. **Windsor, Can.**

Offices in All Principal Cities



There aren't any books about magnet wire—

The making of magnet wire is a difficult, complicated process, and the buyer of the finished product has little to guide him save his own experience and the reputation of the manufacturer who supplies him.

The latter is a powerful reason for buying Acme Wire.

We have been making magnet wire for sixteen years; being the first firm to successfully market enameled wire. The Acme plant is equipped with the most up-to-date facilities, including many machines designed especially for the production of magnet wire that will meet the Acme requirements.

But over and above this splendid mechanical equipment stands another thing which has made the Acme Trade Mark stand for the highest quality in magnet wire, and which has caused users everywhere to have the most implicit confidence in Acme Wire products. This thing is the Acme practice of always making wire to fill the actual winding conditions of the user.

Therefore, when you figure on Acme Wire, consider the fact that you get a wire not only uniform, well-spooled and reliable—but of exceptional winding efficiency, due to its superior ability to *"go in the space."* This means reduced winding costs; freedom from trouble with lumps; more and better windings per day; operators who are better satisfied and able to make higher wages.

And also, because we have studied the growing demand for combination insulations of fibre and enamel, we have developed cotton- and silk-covered enameled wires of the most improved type under the trade names of "Cottonite" and "Silkenite"; wires that are capable of replacing heavier double-insulated kinds on all sorts of jobs, with gratifying results.

Some Users of Acme Magnet Wire

Atwater Kent Mfg. Co.
Azor Motor Mfg. Co.
Century Electric Co.
Dayton Engineering Laboratories Co.
Delco-Light Co.
Diehl Mfg. Co.
Eisemann Magneto Corporation
Electric Specialty Co.
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Emerson Electric Mfg. Co.
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Ford Motor Co.
Gray & Davis, Inc.
Holtzer-Cabot Electric Co.
Hoover Suction Sweeper Co.
Klaxon Co.
Robbins & Myers Co.
Sangamo Electric Co.
U. S. Auto Supply Co.
Westinghouse Elec. & Mfg. Co.
Willys Corporation
S. A. Woods Machine Co.

Acme Wire Products Include

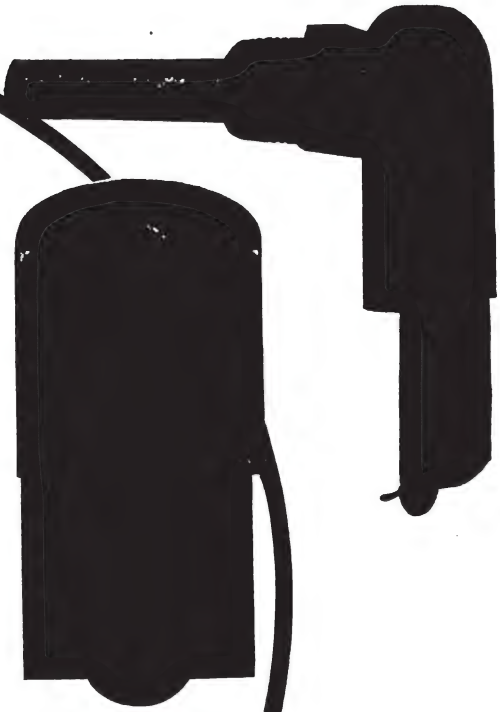
"Enamelite," plain enameled Magnet Wire; "Cottonite," Cotton-covered Enamelite; "Silkenite," Silk-covered Enamelite; Single and Double Cotton Magnet Wire; Single and Double Silk Magnet Wire. We also have a complete organization for the winding of coils in large production quantities.

ACME

THE ACME WIRE CO., New Haven, Conn.
NEW YORK CLEVELAND CHICAGO

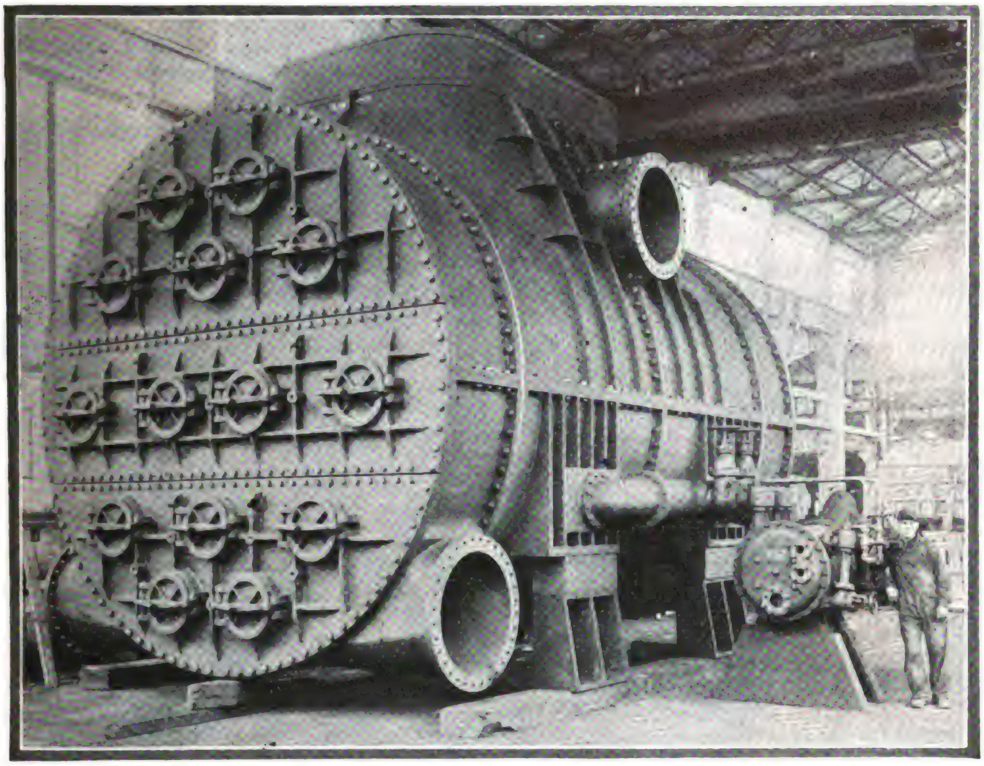
Acme Wire

"It goes in the space"



"JOHN CRANE"

Metallic Packing for Condenser Tubes



"John Crane" Flexible Metallic Condenser Tube Packing used throughout on this 40,000 sq. ft. condenser containing 9,550 1" tubes of copper 16' - 3 - 1/8" over-all No. 18 B. W. G. Built by Wheeler Condenser and Engineering Co. of Carteret, N. J.

Send For This Book

A brief but complete illustrated text on condenser tubes and their packing explaining the bonding of tubes to tube sheet to prevent electrolytic action. Tells actual facts in the elimination of enormous expense in replacements by prolonging tube life. Suggests as a very logical conclusion the use of the John Crane Process of Condenser Tube Packing. Write on letterhead, please.

Don't Expect "John Crane" Results Unless You Buy Original Genuine "John Crane" Metallic Packing.

Crane Packing Company

1804 Cuyler Avenue, Chicago

NEW YORK: 710 Dodge Bldg.

PHILADELPHIA: 108 Walnut Street

HOUSTON: 405 Scanlan Bldg.

CANADA: Flexible Metallic Packing Co., Ltd., Windsor, Ont.

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A section is devoted to current Institute news, notices of meetings, reports of committees and of Section and Branch meetings, news of allied societies, personal items, etc.

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Gives standard definitions of electrical terms, technical data, standard performance, specifications for tests of electrical machinery, standard voltages and frequencies, and general recommendations, as adopted by the Standards Committee and approved by the Board of Directors of the A. I. E. E. It also contains "Rules for Electrical Machinery" of the International Electrotechnical Commission.

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These features please motor users

Why shouldn't they? For each and every one of them is the result of a demand on the part of these same motor users.

For over ten years our men in the field have been gathering data on what motor users want and the Pow-R-full Motor supplies them all.

These features are just what you want in your motor. Bulletin 1296 describes and illustrates many important features of Wagner Pow-R-full motors. Ask for it.

Wagner Electric Manufacturing Company,
Saint Louis, Missouri

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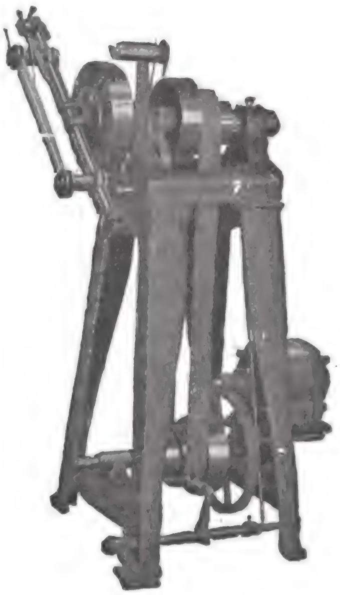
Wagner Quality **Pow-R-full Motor**
Polyphase

"Superior Coil Winding Machine"

The machine which will meet all your Coil Winding requirements



MOTOR gear driven, built for heavy duty as well as for light coil winding.

Write for particulars which will give you complete information concerning this machine.

Armature Coil Equipment Co.
3202 Scranton Road
CLEVELAND - OHIO
Manufacturers of Motor Repair Equipment

SPHERICAL PHOTOMETERS

40"-60" and 80" SPHERES

Using the Built In
SHARP-MILLER PHOTOMETER
Scale range 40-4500 lumens

Calibrated by The Electrical Testing Laboratories
No dark room required

COMPLETELY EQUIPPED FOR
MULTIPLE AND STREET SERIES LAMPS

CENTRAL STATIONS

MAINTAIN YOUR STREET LIGHTING
REQUIREMENTS UP TO STANDARD

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Foote, Pierson & Co., Inc.
160-162 Duane St., New York City

For All Industries

IN meeting the power requirements of mine, mill or factory, the transformer problem is generally present.

Kuhlman Transformers have been giving universal satisfaction in a wide range of industries, because they are ***"Built to Fit the Need"***, and operate economically, safely and reliably.

All essential refinements of modern transformer engineering are embodied in each Kuhlman product, as well as many other features, throughly proved, found only in apparatus of our manufacture.

Write us on your next industrial transformer problem.

Detailed information and bulletins supplied on request.

Prompt deliveries of transformers for all purposes.

Kuhlman Electric Company
Bay City, Michigan
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KUHLMAN TRANSFORMERS

Since 1893

A NEW CATALOG

We have just issued *Catalog J-985*, entitled *"Megger" and "Bridge Megger" Testing Sets*.

It contains considerable information that should prove helpful to every engineer who is interested in the subject of *insulation resistance*—with respect to generators, motors, transformers, switchboards, insulators, cables, interior wiring, etc.

Write for copy today.

JAMES G. BIDDLE
1211-13 Arch Street, Philadelphia

New Departure Ball Bearings

have even more important advantages than power saving.

—They do not need constant lubrication or adjustment.

—They do not wear. No sagging of armature on pole pieces.

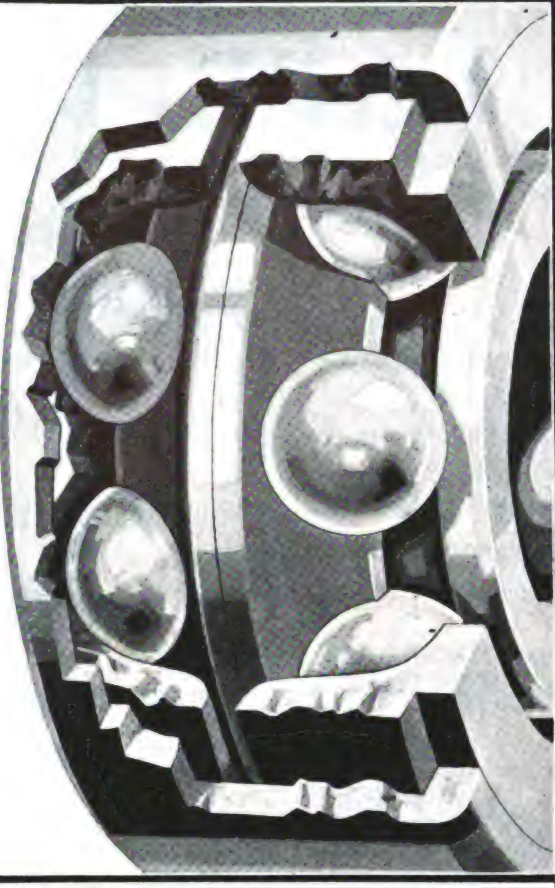
—Steady armature running means good commutation.

May we send selected Engineering Bulletins showing ball bearings in electrical machinery?

The New Departure Manufacturing Co.

Bristol, Connecticut

Detroit **Chicago**



[Section removed to show construction]

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1. Reduce slippage
2. Decrease belt tension
3. Transmit more power
4. Lower total cost of drive, due to narrower belts.

Whenever you buy a pulley for a motor, get a Rockwood Paper Pulley, the pulley that most every motor is equipped with when it leaves the factory. Rockwood is more than a pulley—*it is pulley service!* Order from your electrical dealer or direct from us.

THE ROCKWOOD MFG. COMPANY
1947 English Avenue , INDIANAPOLIS, U.S.A.

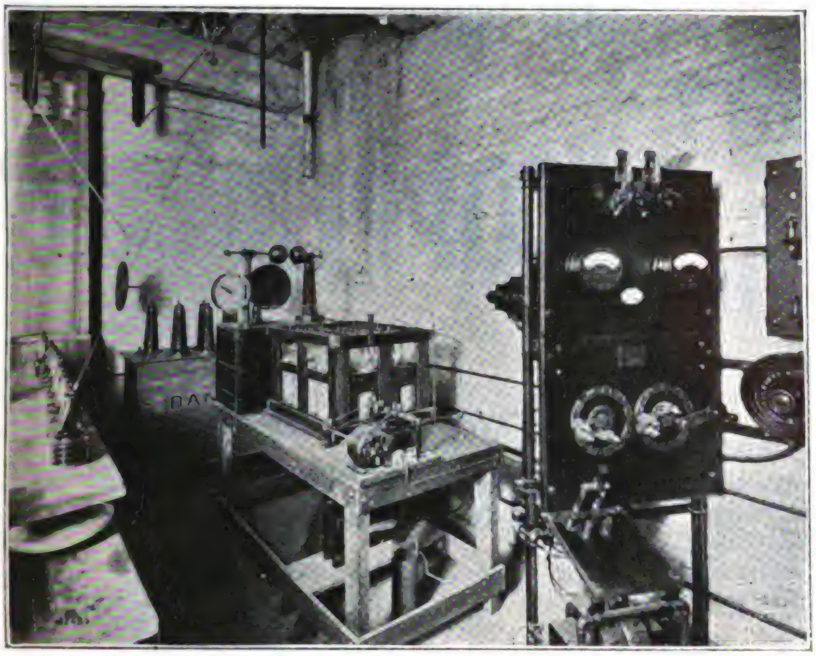
"NORMA" PRECISION BALL BEARINGS

For Fractional H.P. Motors

Saleability, like serviceability, must be built into a motor. Equipping a motor with "NORMA" Bearings gives it a high "factor of saleability", because it eliminates bearing troubles —the principal source of motor dissatisfaction. A "NORMA" equipped motor runs better, keeps cleaner, lasts longer, uses less current, costs less to run—all of which are mighty strong "selling points". And the service expense is materially reduced.

See that your motors have "NORMA" Ball Bearings

THE NORMA COMPANY OF AMERICA
Anable Avenue
Long Island City New York
BALL, ROLLER AND THRUST BEARINGS



HIGH-VOLTAGE TESTING OUTFITS

—designed for both High-Tension, High-Frequency Tests; and High-Tension, Low-Frequency Tests.

An AMERICAN TRANSFORMER apparatus of utmost value to Manufacturers of Ins u l a t o r s, Lightning Arresters, Sheet Insulation, Molded Insulation, Motors, Transformers, etc., and for the conduction of Laboratory tests.

DESCRIPTION—In the extreme rear of illustration is a 60-cycle, 125,000-volt testing transformer, the voltage of which is varied by means of the regulating panel shown in the foreground. The lower section of the voltage-control panel contains the radial switch type regulator. The upper portion of the panel shows the voltmeter, ammeter and circuit breaker. In the center of the picture is a table containing a 200,000-volt, 150,000-cycle high-frequency testing outfit.

Our High-Voltage Testing Outfits, can, of course, be adapted or modified to meet individual needs. More detailed information will be furnished upon receipt of data outlining the kind of testing that is desired.

The American Transformer Company
176 Emmet Street
Newark, N. J.

"Where Transformers Are Made to Fit the Job"

CABLE TERMINAL DEVICES

DISCONNECTING POTHEADS

The advantages of the disconnecting pothead should always be considered carefully before definite decision to use any other is made. The disconnecting feature adds little to the cost and its benefits are almost without limit, depending entirely upon the extent to which you take advantage of them.

The disconnecting pothead is the basis of a system of distribution that is more flexible than any other which could be installed or maintained or operated at anywhere near as low a cost.

Where potheads are to be installed near other manual switches the non-disconnecting pothead or plain cable seal is properly chosen, the disconnecting pothead is often used in connection with automatic switches, cutouts, etc., as it provides a disconnect which can be used in case of repairs or renewals being necessary.

POTHEADS, DISTRIBUTION BOXES

ON LINE EXTENSIONS OR IMPROVEMENTS

In planning for expansion and improvement of your distribution systems take advantage of the G and W Pothead Idea.

The value of your installation is dependent upon the adaptability of your distribution system at a time of sudden need.

Both normal conditions and the requirements of sudden demands, at a time of service interruption can be successfully met with a G and W equipped system.

The experience of the G and W staff is at your service in planning complete equipment to meet the needs of specific installations.

G & W ELECTRIC SPECIALTY CO.
Chicago Illinois

Representatives in
San Francisco, Los Angeles, Seattle, and Calgary, Can.

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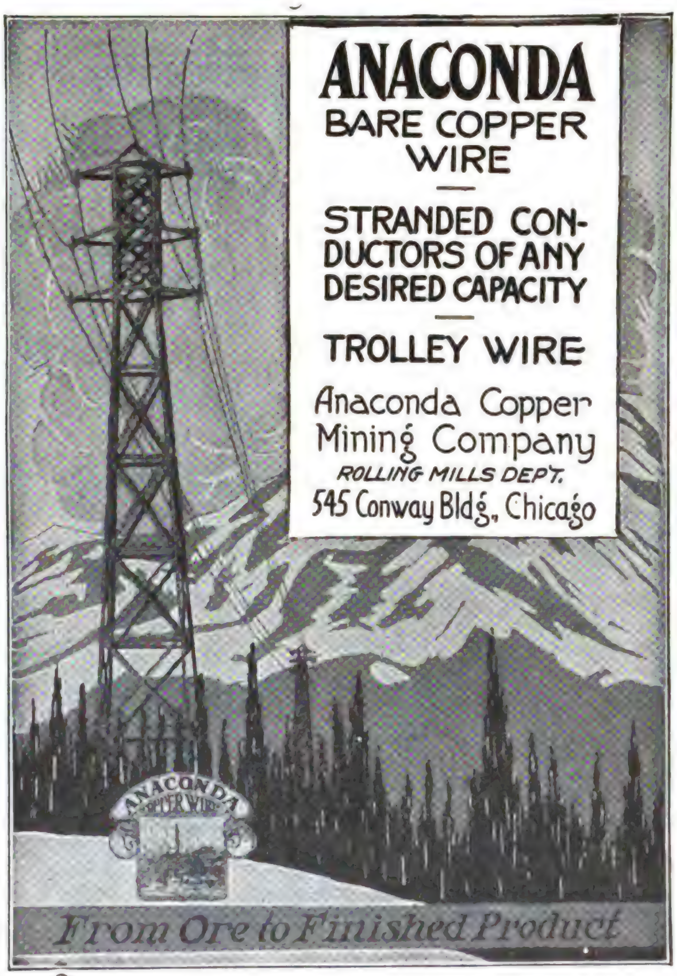
G & W ELECTRIC SPECIALTY CO.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TROLLEY WIRE
Anaconda Copper Mining Company
ROLLING MILLS DEPT.
545 Conway Bldg., Chicago
ANACONDA COPPER WIRE
From Ore to Finished Product

TRADE **TIREX** MARK

(ALL RUBBER)

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Tirex Cord is noteworthy because of its clean outer surface. It may easily be wiped clean when soiled and is always ready for the next job. It does not collect and hold dirt or grease and will not absorb moisture.

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SIMPLEX WIRE & CABLE Co

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Joint Making with STANDARD Paper Jointing Tubes.

Eliminating a Weak Link

A chain is no stronger than its weakest link, and the weakest links in an underground cable system are apt to be the joints unless the latter are made with the greatest care.

STANDARD Jointing Materials

(Paper Jointing Tubes, "Ozite" Insulating Compounds, etc.)

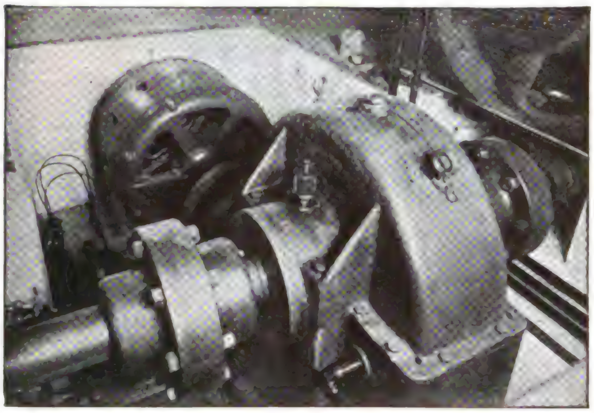
make possible the practical elimination of these weak links even with working pressures as high as 27,000 volts If you are interested in eliminating joint troubles write for Bulletin No 740.

Standard Underground Cable Co.

Boston	Atlanta	Chicago	Seattle	Washington	New York
Pittsburgh	Detroit	Los Angeles	Philadelphia	St. Louis	San Francisco

For Canada: Standard Underground Cable Company, of Canada, Limited, Hamilton, Ont.

Cleveland WORM GEAR REDUCTION UNITS



Cleveland Worm Gear Reduction Unit applied to mill line shaft, Motor 400 H.P.

High-Speed Motors plus Cleveland Worm Gear Reduction Units

Mean both initial and permanent economy. Cleveland Worm Gearing of correct design and right tooth pressure gives a more even flow of torque than is secured by any other device and handles abnormal gear ratios with ease.

Of course the design of tooth and worm and proper materials and proper cuttings are of utmost importance. Those who know what has been done with properly designed worm gearing under the extraordinarily rigid demands of motor truck service with its sudden application of torque will appreciate in some measure the remarkable advance made in industrial worm gearing.

It will be perfectly clear to you why we are able to prove high efficiency; low cost of upkeep; freedom from vibration; greater compactness; greater silence; positive lubrication and low upkeep cost.

Write us for latest worm gear data and put your speed reduction problem up to us.

The Cleveland Worm & Gear Co.

America's Worm Gear Specialists

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DRAVO-DOYLE CO., Pittsburgh
Cleveland, Indianapolis, Philadelphia

New England Representatives
FRANKLIN MACHINE CO., Providence, R. I.

Pacific Coast Representatives
ALFRED H. COATS CO., San Francisco, Cal.

Rocky Mountain States Representatives
THE VULCAN IRON WORKS CO., Denver, Colo.

K & E "SAMSON"

WOVEN MEASURING TAPE

For work around high tension electric currents, the use of a metallic tape is fraught with danger. Our "Samson" tape is of a very heavy and durable weave but *without metal strands* which adapts it particularly to electrical work.

Furnished with the K & E Patent Refill Device In lengths of 25, 30, 75 and 100 ft.

Send for our Catalog

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Drawing Materials · Mathematical and Surveying Instruments · Measuring Tapes

"The PHOTOSTAT Put These People on Our Books"

"Up to six months ago we were never able to 'land' any of Judson Company's contracts, because we couldn't make the deliveries they asked for. Then I happened to read Floyd W. Parson's article in the Saturday Evening Post called 'The Labor Savers' in which he described the PHOTOSTAT. This machine makes photographic facsimiles directly on sensitized paper of drawings, pencil sketches, blue prints, small machine parts, reports, shipping lists, contracts, catalog pages, maps, production charts, telegrams, advertising layouts, and business papers of all kinds.

"We installed a PHOTOSTAT and since that time have been able to get our work into the shop days, and in some cases even weeks, earlier than we used to. The next time we quoted the Judson people we were able to meet their delivery requirements and we landed the contract.

"The PHOTOSTAT makes in a few minutes without error as many copies as we need of the work subjects furnished us, whether they are tracings, pencil sketches or blueprints.

"The PHOTOSTAT has not only made thousands of dollars for us by helping to get new customers, but has also saved us a great deal of time, money and worry in the office. It relieves the stenographers of a lot of copy-work:—does it in far less time and *never makes a mistake.* It also saves our advertising man much time in making layouts. And we use it to reduce drawings to convenient size for filing and to copy important documents when we don't want the originals to leave our files. You know PHOTOSTAT copies are legal evidence in court."

In our booklet "A Good Word for the PHOTOSTAT," many users in widely different industries tell their own experiences with the PHOTOSTAT. Just ask for it.

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Superstructures as well as Substructures

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Valuations and Reports of Public utility, industrial and all other properties
Rate Cases Condemnation Suits
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NEW YORK MILWAUKEE
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Formerly of the Examining Corps of the U. S. Patent Office
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Electrical Transmission of Power
Water Power Plants
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Chas. W Mitchell, Electrical Engineer
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Fire Alarm Engineers & Contractors
Fire Drills, Fire Appliances and Equipment
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HILL & FERGUSON
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Chemical and Biological Laboratories.
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A CARD in the Engineering Directory will keep your name, and the specialized service you are prepared to render, constantly before your prospective clients throughout the year for $40.00. The circulation of the JOURNAL is 20,000 copies monthly.

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For Consultants in the Fields of Engineering, Architecture, Chemistry, Law, Physics, and Related Arts and Sciences

(Cards continued on next page.)

"AK" Variable Speed Motor for Printing Machinery

Highest efficiency under variable load. Wound for 25% overload. Push button control. For A. C. any cycles. In sizes 1/20 to 5 H. P.

Modern, safe equipment for job or cylinder press.

Write for complete information.

NORTHWESTERN ELECTRIC COMPANY
Also Mfrs. of the new "Martin" Rotary Converter.
409 So. Hoyne Avenue, Chicago, Ill.
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STAR
Ball Bearing Motors For All Purposes

Horizontal–Vertical

D. C. Interpole Motors for hard usage—1 to 40 hp. Sparkless commutation at all times.

A. C. Polyphase Motors squirrel cage induction and slipring—all cycles, 1 to 40 hp., 110 to 550 volts.

A. C. and D. C. Generators and Motor-Generator Sets

Write for Bulletins.

Star Electric Motor Co.
Miller St. and N. J. R. R. Ave., Newark, N. J.

MARINE RULES of the A.I.E.E.

Recommended Practise for Electrical Installations on Shipboard

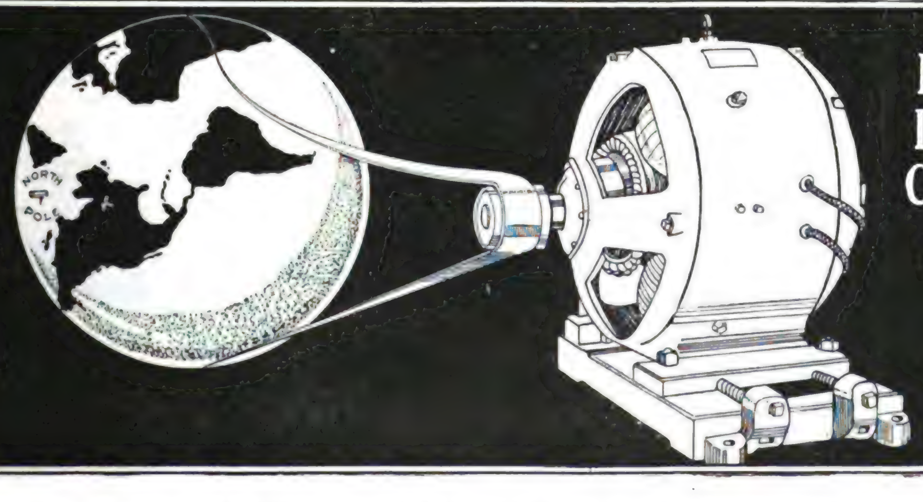
Published December, 1920

THE Marine Rules have been drawn up to serve as a guide for the equipment of merchant ships with electrical apparatus for lighting, signaling, communication and power, but not including propulsion. They indicate what is considered the best engineering practise with reference to safety of the personnel and of the ship itself, as well as reliability and durability of the apparatus. These rules are intended to supplement the STANDARDS of the A. I. E. E., which should be followed wherever applicable.

Linen covered, 97 pp., price, $1.00 per copy, with discount of 25% to members of the A. I. E. E., dealers, and purchasers of ten or more copies.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

A MOTOR THE WORLD CAN DEPEND ON



ELECTRO DYNAMIC COMPANY
BAYONNE, N. J.

Sales Offices in Principal Cities

Classified Advertiser's Index for Buyers

A classified and comprehensive list of manufacturers and agents for machinery and supplies used in the electrical and allied industries; professional consultants and laboratories.

Note: For reference to the advertisements see the Alphabetical List of Advertisers on page 42.

AIR COMPRESSORS
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.

AIR WASHERS.
Spray Engineering Co., Boston

AMMETERS, VOLTMETERS.
(See INSTRUMENTS, ELECTRICAL)

ARMATURE WINDING APPARATUS.
Armature Coil Equipment Co., Cleveland.

BATTERY CHARGING APPARATUS.
Cutler-Hammer Mfg. Co., Milwaukee.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BEARINGS, BALL.
New Departure Mfg. Co., The, Bristol, Conn.
Norma Co. of America, L. I. City, N. Y.
S. K. F. Industries, New York.

BOOKS, TECHNICAL.
Wiley, John & Sons, Inc., New York

BOXES, FUSE.
General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BOXES, JUNCTION.
G & W Elec. Specialty Co., Chicago.
Metropolitan Device Corp., Brooklyn, N. Y.

BRAKES, CAR.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.

BRUSHES, COMMUTATOR.
Carbon
Morganite Brush Co. Inc., New York.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Copper Graphite
Morganite Brush Co. Inc., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BUS BAR FITTINGS.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CABLE ACCESSORIES.
Dossert & Co., New York
G & W Electric Specialty Co., Chicago, Ill.
General Electric Co., Schenectady, N. Y.
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

CABLES.
(See WIRES AND CABLES)

CABLEWAYS.
Roebling's Sons Co., John A., Trenton, N. J.

CAMBRIC, VARNISHED.
Irvington Varnish & Ins. Co., Irvington, N. J

CARBON BRUSHES.
(See BRUSHES, COMMUTATORS.)

CEDAR POLES.
Naugle Pole and Tie Co., Chicago
Page & Hill Co., Minneapolis, Minn.
Partridge Lumber Co., T. M., Minneapolis
Valentine-Clark Co., Minneapolis.

CIRCUIT BREAKERS.
Condit Electrical Mfg. Co., So. Boston, Mass.
Cutter Company, The, Philadelphia
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CLUTCHES, MAGNETIC.
Cutler-Hammer Mfg. Co., Milwaukee.

COIL WINDING APPARATUS.
Armature Coil Equipment Co., Cleveland.

COILS, MAGNET.
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago, Ill.
Dudlo Mfg. Co., Ft. Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDENSER PACKING, METALLIC.
Crane Packing Co., Chicago

CONDENSERS.
Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONNECTORS, SOLDERLESS.
Dossert & Co., New York, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONNECTORS AND TERMINALS.
Dossert & Co., New York
G & W Electric Specialty Co., Chicago, Ill.
Standard Underground Cable Co., Pittsburgh
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONTACTS, TUNGSTEN.
General Electric Co., Schenectady, N. Y.

CONTROLLERS.
Cutler-Hammer Mfg. Co., Milwaukee.
General Electric Co., Schenectady, N. Y.
Rowan Controller Co., Baltimore
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONVERTERS.
Allis-Chalmers Mfg. Co., Milwaukee
Northwestern Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COOLING PONDS.
Spray Engineering Co., Boston

COPPER CLAD WIRE.
Copper Clad Steel Co., Rankin, Pa.
Standard Underground Cable Co., Pittsburgh

CUT-OUTS.
Condit Electrical Mfg. Co., So. Boston, Mass.
General Electric Co., Schenectady, N. Y.
G & W Elec. Spec. Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Thoner & Martens, Boston
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

DRAWING MATERIALS.
Keuffel & Esser, Hoboken, N. J.

DYNAMOS.
(See GENERATORS AND MOTORS.)

ELECTRIFICATION SUPPLIES, STEAM ROAD.
General Electric Co., Schenectady, N. Y.
Ohio Brass Co., Mansfield, Ohio
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ENGINEERS, CONSULTING AND CONTRACTING.
(See PROFESSIONAL ENGINEERING DIRECTORY.)

ENGINES. *Gas & Gasoline.*
Allis-Chalmers Mfg. Co., Milwaukee
Oil
Allis-Chalmers Mfg. Co., Milwaukee
Steam
Allis-Chalmers Mfg. Co., Milwaukee

FANS, MOTOR.
Century Electric Co., St. Louis.
General Electric Co., Schenectady, N. Y.
Star Electric Motor Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FARM LIGHTING GENERATORS.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FIBRE.
Diamond State Fibre Co., Bridgeport, Pa.
National Fibre & Ins. Co., Yorklyn, Del.

FURNACES, ELECTRIC.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FUSES. *Enclosed Refillable*
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Enclosed Non-Refillable
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Open Link
General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
High Tension
Metropolitan Device Corp., Brooklyn, N. Y.
Railway & Industrial Engg. Co., Greensburg, Pa.

GEARS, FIBRE.
Diamond State Fibre Co., Bridgeport, Pa.
General Electric Co., Schenectady, N. Y.

GEARS, REDUCTION and HERRINGBONE.
Cleveland Worm & Gear Co., Cleveland

GENERATORS AND MOTORS.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Century Electric Co., St. Louis.
Electro-Dynamic Co., Bayonne, N. J.
General Electric Co., Schenectady, N. Y.
Northwestern Electric Co., Chicago
Star Electric Motor Co., Newark, N. J.
Wagner Elec. Mfg. Co., St. Louis, Mo.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GENERATING STATION EQUIPMENT.
Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GROUND RODS
Copper Clad Steel Co., Rankin, Pa.

HEADLIGHTS.
Ohio Brass Co., Mansfield, O.

HEATERS, INDUSTRIAL.
Cutler-Hammer Mfg. Co., Milwaukee.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

INDICATORS, SPEED.
Biddle, James G., Philadelphia
Hasler-Tel Co., New York.
Roller-Smith Co., New York

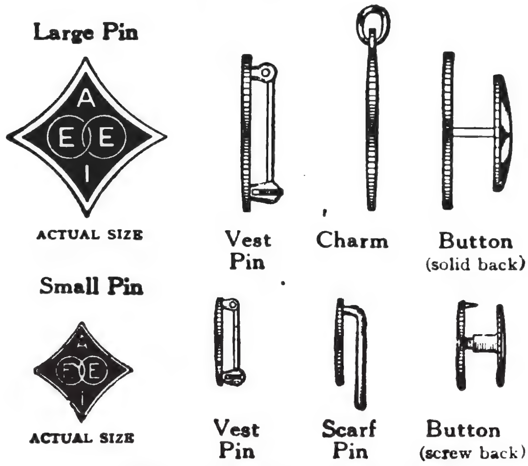
INSTRUMENTS, ELECTRICAL.
Graphic
Biddle, James G., Philadelphia
Bristol Co., The, Waterbury, Conn.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Indicating
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Integrating
Biddle, James G., Philadelphia
Duncan Elec. Mfg. Co., Lafayette, Ind.
General Electric Co., Schenectady, N. Y.
Roller-Smith Co., New York
States Co., The, Hartford, Conn.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Repairing & Testing
Electrical Testing Laboratories, New York
Scientific, Laboratory, Testing
Biddle, James G., Philadelphia
Foote, Pierson & Co., Inc., New York
General Electric Co., Schenectady, N. Y.
Leeds & Northrup Co., Philadelphia
Metropolitan Device Corp., Brooklyn, N. Y.
Roller-Smith Co., New York
States Co., The, Hartford, Conn.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Telegraph
Foote, Pierson & Co., Inc., New York
Waterbury Button Co., Waterbury, Conn.
Western Electric Co., All Principal Cities
Wireless
Acme Apparatus Co., Cambridge, Mass.
General Radio Co., Cambridge, Mass.
Waterbury Button Co., Waterbury, Conn.

INSULATING MATERIALS.
Cloth
Irvington Varnish & Ins. Co., Irvington, N.J.
Minerallac Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Composition
American Insulator Corp., New Freedom, Pa.
Belden Mfg. Co., Chicago
Cutler-Hammer Mfg. Co., Milwaukee.
Electrose Mfg. Co., Brooklyn, N. Y.
Hopewell Ins. & Mfg. Co., Hopewell, Va.
Redmanol Chemical Products Co., Chicago
Waterbury Button Co., Waterbury, Conn.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Compounds
Minerallac Electric Co., Chicago
Fibre
Diamond State Fibre Co., Bridgeport, Pa.
National Fibre & Ins. Co., Yorklyn, Del.
Lava
American Lava Co., Chattanooga, Tenn.
Paper
Irvington Varnish & Ins. Co., Irvington, N. J.
Silk
Irvington Varnish & Ins. Co., Irvington, N. J.

Classified Advertiser's Index for Buyers—*Continued.*

A. I. E. E. MEMBERSHIP BADGES

STYLES OF BADGES



PRICES OF BADGES

Size	Style Back	Price	Style No.
Large	Vest Pin	$4.50	1
Large	Charm	4.50	2
Large	Lapel Button (Solid Back)	6.00	3
Small	Vest Pin	3.00	4
Small	Scarf Pin	3.50	5
Small	Lapel Button (Plated Screw Back)	3.00	6

THE membership of the Institute is privileged to wear the official badge of the society in the various styles shown herein.

All the membership badges are of solid 14k gold, excepting the small size lapel button, the screw back of which is of plated gold. The enameled background is maroon for Associates and blue for Members, with letters and border in gold. The Fellow badge is the reverse in color of that provided for Members.

Upon transfer to the Member grade an Associate badge (large size only) can be reenameled blue at a cost of $1.00. The small badges and the large size Member badges cannot be reenameled; a credit of $.75 for a small badge and $1.00 for a large badge ($1.25 for large lapel button) will be allowed, however, upon the return of a badge to Institute Headquarters, to apply as part payment for a new badge. This credit is also allowed to those members who desire to exchange a large size badge for the smaller size.

Orders for badges should be accompanied by remittance and should indicate Badge Style Number (see price-list) desired.

American Institute of Electrical Engineers
33 West 39th Street, New York

Classified Advertiser's Index for Buyers—*Continued.*

If a Heavy Static Torque Is Required Install

Century REPULSION START INDUCTION Single Phase Motors

Ratings 1/8 to 40 H.P.

which are extensively used for the operation of air compressors, refrigerating machines, plunger pumps, wood working and similar machinery. They develop a static torque greater than 275% of full load torque with a starting current less than 260% of full load value.

Temperature Rise Not More Than 40° Centigrade

THEY KEEP-A-RUNNING

Century Electric Co.

St. Louis, Mo., U. S. A.

Sales Offices in Principal Cities

ALPHABETICAL LIST OF ADVERTISERS

(For classified list of Advertisers see Pages 36, 38 and 40)

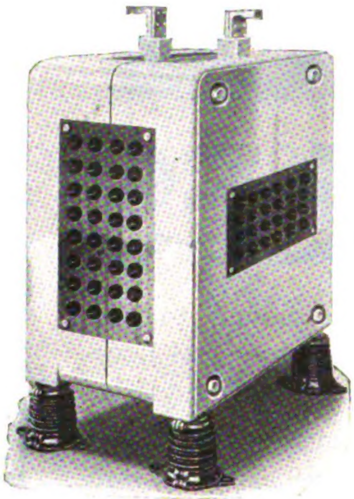
Hell Gate Station

The largest power plant in the world has installed

Metropolitan Reactors

as standard equipment throughout

Outdoor Service Reactance Coils, 25 to 250 Amp.



Indoor Service Reactance Coils, 25 to 350 Amp.

Short Circuits

in your system cannot be prevented—as yet!

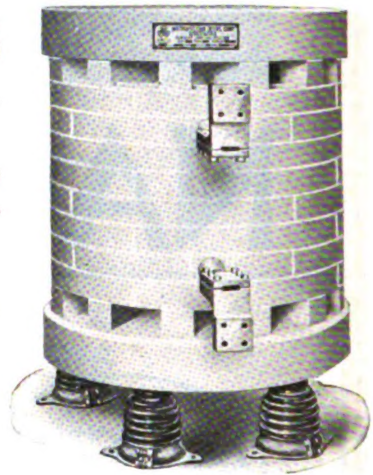
Do the next best thing, protect your equipment from abnormal and dangerous stresses.

Install Metropolitan Current Limiting Reactors

and have

maximum { short circuit protection, reactance, efficiency

minimum { energy losses, space requirement, temperature rise



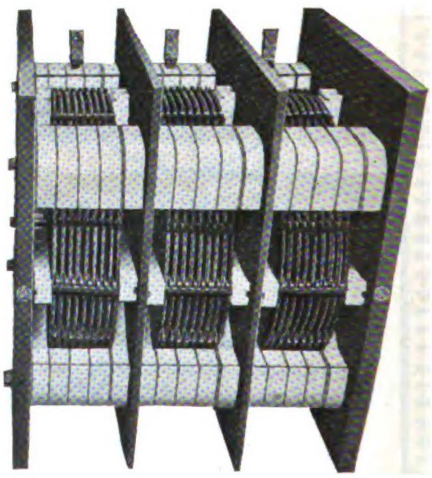
Indoor Service Reactance Coils, 350 to 750 Amp.

Indoor Service Reactance Coils, 750 to 3000 Amp.

Metropolitan Device Corporation

1250 Atlantic Avenue
Brooklyn, N. Y.

M D C



Three-phase Feeder Reactance Coil

METROPOLITAN DEVICE CORPORATION,
1250 Atlantic Ave., Brooklyn, N. Y.

Gentlemen: Please send data and full information on current-limiting reactors.

Name of Company ....
By .... Title ....
Address ....
Date ....

The Okonite Co., 1513 Candler Bldg., Atlanta, Ga.

American Institute of Electrical Engineers

COMING MEETINGS

Pacific Coast Convention, Vancouver, B. C., August 8-11.

MEETINGS OF OTHER SOCIETIES

American Electrochemical Society, Montreal, Sept. 21-23. Fall Meeting.

Association of Iron and Steel Electrical Engrs., Cleveland, O., Sept. 11-15. Annual Convention.

Illuminating Engineering Society, Boston, Sept. 25-28.